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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1956 SUMMER MEETING IN THE EAST

AT

NEW HAVEN, CONNECTICUT

June 21–22–23

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1956 SUMMER MEETING IN THE EAST, NEW HAVEN, JUNE 21, 22, AND 23, 1956

THE **1956 "Summer Meeting in the East"** of the American Physical Society will be held in New Haven, Connecticut, in the buildings of Yale University, on Thursday, Friday, and Saturday, **June 21, 22, and 23, 1956.** All sessions will be in or near the Sloane Physics Laboratory at 217 Prospect Street. Our Division of Electron Physics makes this its principal meeting of the year and has provided both invited and contributed (ten-minute) papers; the rest of physics is by no means neglected, and the programme is well rounded. We seldom have an opportunity to meet in New England, largely because most of the academic centers do not have a sufficiency of hotels. This will be the first meeting held at Yale University since 1932: it is hoped that many will take advantage of the rare and valued opportunity. The Chairman of the Local Committee is Professor W. W. Watson, to whom and to whose colleagues we shall be greatly indebted.

Living quarters will be available, for men, women, couples, and families, in the Silliman and Timothy Dwight Colleges of Yale University from Wednesday evening, June 20, to Saturday afternoon, June 23. The rate is $4 per night per person, except that for a child under twelve only $2 per night need be paid. Advance reservations must be made: write promptly to Mrs. D. W. Gordon, Sloane Physics Laboratory, Yale University, New Haven 11, Connecticut.

Recommended hotels are the following: Taft (singles $5.50 to $7.50, doubles $9 to $11) and Duncan (singles $5 to $6, doubles $8 to $10). Both are in the city of New Haven at a few minutes' walk from Sloane Physics Laboratory. Write promptly to either, not failing to mention that you are coming to the meeting of the American Physical Society. New motels are the New Haven Motor Inn and the Rip Van Winkle Motel, both on the Merritt Parkway at exit 59, and the Tremont Motor Courts near the Yale Bowl.

The **registration desk** will be located in the Sloane Physics Laboratory, 217 Prospect Street. Members and guests are asked to register and to consult frequently the nearby bulletin boards for messages and notices pertaining to the meeting. A registration fee of one dollar will be asked.

Invited papers will be given on the general programme by G. A. Anslow, E. R. Beringer, P. J. Bray, W. L. Brown, T. J. Carroll, J. S. Foster, H. Margenau, R. W. Morse, A. S. Nowick, N. F. Ramsey, H. Reiss, H. L. Schultz, R. B. Setlow, and L. P. Wheeler. We have not neglected the opportunity of calling upon Yale University and some of its graduates. **Invited speakers of the Division of Electron Physics** are L. M. Branscomb, G. R. Brewer, S. C. Brown, V. Hughes, K. G. McKay, E. W. Mueller, F. J. Norton, and W. G. Shepherd.

One hundred and thirty-eight contributed papers are distributed among twelve sessions. This figure appears to exceed the corresponding figures of any June meeting of the past, the 1955 Toronto meeting alone excepted—and at Toronto the Canadian Association of Physicists helped considerably to expand the programme. The Society owes a dept to H. D. Hagstrum of the Division of Electron Physics for advising the Secretary on the distribution of the contributed papers in electron physics and in the so-nearly-allied field of semiconductor physics. We decided to ask the members to put up with a few inconvenient simultaneities rather than withstand the allurements of a free Saturday afternoon in New Haven.

The **banquet of the Society** will be held on Friday evening at seven in the University Dining Hall. The after-dinner speakers will be L. W. McKeehan and E. C. Pollard, perhaps others. The price will be $3.25. Use may be made of the form on the final page of this Bulletin to make advance reservations. The deadline hour for purchase of tickets at the meeting will be announced at the registration desk.

Yale University invites our members and guests

to a **punch party** on Thursday afternoon from 5 to 6:30. The place will be announced at the registration desk.

A programme of **entertainment for the ladies** is being prepared, comprising tours and other diversions. Details will be provided at the registration desk.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special importance, will be considered for admission to a special supplementary programme if the abstracts are received at the office of the Society (the address below) not later than Friday, June 16. The abstracts must be composed according to the usual rules, and two copies must be submitted of each; they will not be published. The titles of such papers as may be accepted will be written on a blackboard near the registration desk, and these papers will be scheduled for presentation at the end of Session G.

The **Council of the American Physical Society,** if convoked to meet at New Haven, will be so informed by special notice to its members.

Prospective meetings and deadlines of the Society are listed on page 277 of this Bulletin, together with instructions for the preparation of abstracts.

Errata pertaining to abstracts in this issue will be published in a subsequent issue of this Bulletin if received not later than Monday, June 25, by Miss Ruth Bryans, American Institute of Physics, 57 East 55th Street, New York 22, New York. Do not send in the abstracts marked with corrections. Write out the corrections in the form "Instead of . . . read. . . ." Add nothing.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

Preliminary Announcement of the 1956 Thanksgiving Meeting

This is the occasion when the gap between the last (and first) pre-deadline announcement and the final announcement of a meeting is the longest of the year. Do not forget that the deadline for the 1956 Thanksgiving meeting will be Friday, September twenty-first. *A fortiori* do not forget that the meeting itself will be held at Chicago, in the buildings of the University of Chicago, on Friday and Saturday, November 23 and 24, 1956. The official hotel will be the Windermere, at 1642 East 56 Street, Chicago 37, Illinois. After it is fully booked, the Windermere will place in other neighboring hotels those of our members who apply to it.

Division of High-Polymer Physics

Our Division of High-Polymer Physics announces that it will co-sponsor a part of the Thirtieth Colloid Symposium, this part consisting of a Symposium on diffusion in liquids and polymers and a Symposium on flow processes in polymers. Both will be full-day symposia, and the dates will be June 20 and June 21 (1956), respectively. The place will be the University of Wisconsin, Madison, Wisconsin. Details may be obtained from Dr. W. James Lyons, Quartermaster Research and Development Command, Natick, Massachusetts.

Wanted

The American Physical Society would like to buy the following copies of *The Physical Review* for 1955: January 1, January 15, April 1, and July 1. Payment of $1.50 per copy will be made. Copies should be sent to Mr. Wallace Waterfall, American Institute of Physics, 57 East 55th Street, New York 22, New York.

MEETINGS AND DEADLINES FOR THE SEASON 1956–1957

Place	*Meeting dates*	*Deadline date*
Eugene*	June 21–23	past
New Haven	June 21–23	past
Chicago	November 23–24	September 21
Monterey,* California	December 27–28–29	October 19
New York	January 30–February 2	November 23
Norman, Oklahoma	March 1–2	December 21
Philadelphia	March 21–23	January 18, 1957
Washington, D. C.	April 25–27†	February 15†
Notre Dame, Indiana	June 20–22	to be announced
Boulder,* Colorado	September 5–7	to be announced

* Abstracts for the Monterey and Boulder meetings are to be sent to W. A. NIERENBERG, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date.

Abstracts for the other meetings listed above are to be sent to KARL K. DARROW, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. To avoid chance of confusion, please do not send an abstract for any meeting until the deadline date of the previous meeting is at least five days past. *The privilege of contributing papers to meetings of the American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

† Possibly subject to change if the National Academy of Sciences should deviate from the customary dates for its spring meeting.

RULES PRESCRIBED FOR ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten and double-spaced; one must be an original, the other may be an original or a carbon copy. Each abstract must be confined to a single page: if it is too long for a single page it is too long to be printed. *Henceforth, if we receive an abstract typed on two pages, we shall print only its first page.* Write each abstract as a single paragraph: the suppression of paragraphs costs time and labor to the editors. Do not use very thin paper; a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. Look at the abstracts in this *Bulletin* to see how the title of the paper and the name of the author are to be arranged, and follow the example. Issues of the *Bulletin* are sometimes appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line. **By action of our Council, abstracts will not henceforth be withdrawn from our proofs unless the asker sends ten dollars with his request.**

EPITOME OF THE 1956 NEW HAVEN MEETING

(Personal names are those of invited speakers, except at the ends of lines where they are the names of halls.)

Thursday Morning

A. Electron emission; Shepherd, Brewer. 59 Sloane.

B. Reactions of transmutation and nuclear energy levels. 57 Sloane.

C. Radio-frequency spectroscopy. 110 Sterling.

D. X-rays and optical spectroscopy; Margenau. 160 Sterling.

Thursday Afternoon

F. Reiss, W. L. Brown; mostly semiconductors. 110 Sterling.

G. Beringer, Schultz, Ramsey; post-deadline papers, if any. Sage Hall.

H. Gaseous electronics. 59 Sloane.

I. Cryogenics. 57 Sloane.

Friday Morning

K. Nuclear physics; Bray. 59 Sloane.

L. General physics. 57 Sloane.

N. Germanium and silicon. 110 Sterling.

P. Mueller, Norton, Anslow, Setlow, Sage Hall.

Friday Afternoon

R. Neutrons, beta emitters, mesons, cosmic rays. Sage Hall.

S. Branscomb, Hughes, S. C. Brown, McKay. 110 Sterling.

U. Magnetism; cyclotron resonance. 59 Sloane.

Friday Evening at Seven

Banquet of the American Physical Society. McKeehan, Pollard. University Dining Hall.

Saturday Morning

V. Nowick, Morse; solid-state physics. 110 Sterling.

W. General electron physics. 59 Sloane.

X. Theoretical physics. 57 Sloane.

Y. Foster, Wheeler, Carroll. Sage Hall.

PROGRAMME

THURSDAY MORNING AT 10:00

59 Sloane

(J. B. JOHNSON presiding)

Mainly Electron Emission

A1. Polycrystalline Field Emission Cathodes. E. G. BROCK, *General Electric Research Laboratory.*—Polycrystalline tungsten samples have been prepared for observation in the field emission microscope by bending a tungsten wire and etching a tip at the bend.[1] In one instance five distinct grains were produced on a tungsten field emission cathode tip of 0.3 micron radius. The grain boundaries are readily discernible in the field emission patterns from tips that have been cleaned by heating to 2400°K. They appear as regions of low electron emission. An analysis of the relative orientation of the grains obtained from the field emission patterns of a polycrystalline tip will be given. This method of preparing and studying polycrystalline samples seems applicable to materials other than tungsten.

[1] The author is indebted to Professor E. W. Müller for suggesting this method.

A2. Higher Order Corrections to the Field Emission Current Formula. P. H. CUTLER AND R. H. GOOD, JR., *The Pennsylvania State University.*—In a recent extension of the Fowler-Nordheim theory to finite temperatures,[1] based on the free electron and image force barrier model, an approximate expression for the current emitted from a metal as a function of temperature and applied electric field was obtained. The values of field and temperature at which the formula for the current applies were established, but a quantitative discussion of the approximations involved was not made. The purpose of the present work is to determine the size of the higher order corrections to the current formula. The procedure used was to include higher order terms in the expansions made to obtain the results. Analytic expressions for the correction terms have been obtained. In the zero temperature limit (Fowler-Nordheim region) the correction to the current formula amounts to five or ten percent of the total current.

[1] E. L. Murphy and R. H. Good, Jr., Phys. Rev. (to be published).

A3. Secondary Electron Current from a Pulsed Electron Accelerator. A. E. EVANS, JR., D. V. BREITENBECHER, D. W. CADY, AND L. L. ANTES, *Aeronautical Research Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.*—A 2-Mev electrostatic accelerator with a 0.06-microsecond pulsed electron source was found to produce radiation afterpulses occurring as late as 150 microseconds after cessation of the source pulse. The rate of afterpulsing was roughly proportional to the pressure in the acceleration and drift tube for pressures up to 5×10^{-6} mm of mercury and rose more steeply at higher pressures. The decay curve of the delayed radiation was independent of the target material and the type of detector used to study it. The energy spectrum was continuous, with an average energy less than that of the bremsstrahlung pulse. The cause of the effect has been determined to be ionization in the drift tube by the primary electron beam. The mechanism for formation of the afterpulses and the instrumentation for their study are discussed.

A4. Single-Pulse Measurements of Secondary Electron Emission from Insulators. A. B. LAPONSKY AND N. REY WHETTEN, *General Electric Research Laboratory.*—Secondary electron emission measurements on insulators are sometimes limited by charging of the surface and by electron bombardment damage. In order to reduce the number of bombarding electrons per measurement, the single-pulse techniques of Johnson and McKay have been modified so that charge, rather than current, is detected. In addition the amplifier band width may be reduced so as to increase the signal-to-noise ratio. Using this method, a bombarding charge per measurement of 10^{-14} coulomb is readliy obtained. Three methods of returning a MgO crystal to the original potential after each measurement have been compared. (1) The crystal is heated so that it becomes conducting, (2) a nearby filament is heated so that thermionic electrons charge the surface down to the potential of the filament, and (3) the surface is charged to the collector potential by secondary emission. Of the three methods, (1) and (2) are in agreement to within the accuracy of our measurements.

A5. Energy Distribution of Secondary Electrons from MgO Single Crystals. N. REY WHETTEN AND A. B. LAPONSKY, *General Electric Research Laboratory.*—The pulse techniques described in the preceding paper have been employed to investigate some secondary emission properties of single crystals of MgO. The energy distribution of the secondaries is obtained using an electrostatic retarding potential method. Measurements are made in a vacuum of 10^{-10} mm on thin single crystals of MgO cleaved in air along the (100) plane. The maximum secondary emission ratio has been found to be as high as 16. The most probable energy of the secondary electrons lies between 1.0 and 1.5 electron volts. Energy distributions of the secondaries have been obtained at a number of primary electron energies. The proportion of low-energy secondaries increases as the primary electron energy is increased. If one assumes that the production process of internal secondaries does not change with primary energy, then the difference in the energy distributions may result from the different average distances that the secondaries travel in the crystal.

A6. Evaporation Rates of Thermionic Cathodes by X-Ray Emission Spectrography. M. D. GIBBONS, V. L. STOUT, AND P. D. ZEMANY, *General Electric Research Laboratory.*—X-ray emission spectrography has been used to determine amounts of evaporation products from BaO, and (BaSr)O coated cathodes, and to measure evaporation from dispenser-type cathodes obtained from the Philips Company. The x-ray techniques and an experimental tube used in making these measurements are described. Evaporation rate measurement determined by x-ray emission spectrography are in agreement with previous result obtained by other methods.

A7. Characteristics of High Current Ion Sources. C. B. MILLS, *Curtiss-Wright Corporation, Research Division.*—High current ion sources are optimized in this study for ion beam stability so that a neutralizing plasma would permit ion beam focus by magnetic lens methods with small space charge forces.

With a sharply focused beam for a monitor, the various processes were studied for electric gradients of the order of 60 kv/cm, ion currents of 0.2 ampere, ion plasma densities of 10^{14} ions/cc and temperatures of the order of 30 ev, and magnetic field intensities of 7000 oersteds. The several processes limiting the ion current are briefly discussed.

Invited Papers (*D.E.P.*)

A8. Influence of the Cathode Base on the Properties of Oxide Cathodes. W. G. SHEPHERD, *University of Minnesota.* (30 min.)

A9. The Formation of High-Density Electron Beams. G. R. BREWER, *Hughes Aircraft Company.* (25 min.)

THURSDAY MORNING AT 10:00

57 Sloane

(E. C. POLLARD presiding)

Reactions of Transmutation and Nuclear Energy Levels

B1. Energy Levels of Be^9.* C. K. BOCKELMAN,† A. LEVEQUE,‡ AND W. W. BUECHNER, *M.I.T.*—The MIT-ONR electrostatic generator and the broad-range spectrograph were used to obtain information on the energy levels of Be^9. Magnetic analysis of the α particles emitted under 7-Mev deuteron bombardment of a thin B target showed groups corresponding to the broad state at 3.04 Mev[1] and to the well-known sharp state at 2.43 Mev in Be^9. In addition, a broad distribution of α particles was observed, the edge of which lay at the position expected for the threshold of the $B^{11}(d,\alpha n)Be^8$ reaction. The ground-state group of the $B^{10}(d,t)B^9$ reaction was observed with $Q=-2.187\pm0.010$ Mev. A second experiment, analyzing the inelastic protons from a 7-Mev proton bombardment of a thin Be target was consistent with the observations above, and with a previous measurement.[2] The width of the 3.04-Mev state is at least 280 kev.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† Now at Yale University.
‡ Permanent address, Centre d'Etudes Nucléaires de Saclay.
[1] L. L. Lee and D. R. Inglis, Phys. Rev. **99**, 96 (1955).
[2] Gossett, Phillips, Schiffer, and Windham, Phys. Rev. **100**, 203 (1955).

B2. Alpha-Particle Bombardment of Magnesium Isotopes.* H. G. GRAETZER AND A. B. ROBBINS,† *Yale University.*—Separated isotopes of Mg^{24}, Mg^{25}, and Mg^{26} have been bombarded with the 8-Mev alpha beam of the Yale cyclotron. Reaction protons were observed at 90° with a proportional counter. The residual nuclei are Al^{27}, Al^{28}, and Al^{29}, respectively The following ground-state Q values and excited states were found: for $Mg^{24}(\alpha p)Al^{27}$, $Q_0=-1.63\pm0.07$, and excited states at 0.85, 1.06, 2.17, and 2.64 (±0.04); for $Mg^{25}(\alpha p)Al^{28}$, $Q_0=-1.29$ Mev, and excited states at 1.00, 1.57, 2.18, 2.54, and 2.96 (±0.04); for $Mg^{26}(\alpha p)Al^{29}$, $Q_0=-2.90$ Mev, and a probable excited state at 1.69 ± 0.04. The $Mg^{24}(\alpha p)Al^{27}$ ground state was calculated from a range cell measurement of the alpha-beam energy. This result and all other excited states were calibrated against the inverse reaction $Al^{27}(p\alpha)Mg^{24}$, whose Q value has been obtained by Donahue[1] with high precision. The levels in Al^{27} and Al^{28} confirm previous results obtained by inelastic proton scattering and deuteron bombardment of natural aluminum. No previous information on Al^{29} is available.

* This work was performed under the joint auspices of the Office of Naval Research and the U. S. Atomic Energy Commission.
† General Electric Predoctoral Fellow.
[1] Donahue, Jones, McEllistrem, and Richards, Phys. Rev. **89**, 824 (1953).

B3. Energy Levels of Al^{25} between 4.2- and 6.4-Mev Excitation Energy.* H. W. LEWIS AND W. T. JOYNER,† *Duke University.*—The differential cross section for the reaction $Mg^{24}(p,p'\gamma)$ has been measured for incident proton energies bewteen 1.5 and 4.2 Mev by observation of the gamma radiation, the target being a 12-kev layer of natural magnesium evaporated onto a one-micron nickel backing. Seven resonances were found in this region. Angular distribution measurements were made at six of these resonances on both the gamma radiation and on the inelastically scattered protons, using the same 12-kev target for the former and a 35-kev target of natural magnesium foil for the latter. A low yield from the reaction $Mg^{26}(p,p'\gamma)$ was observed at the higher energies, with no Mg^{25} contribution in the region studied. The gamma radiation was found to be sysmmetric fore-and-aft in every case. With the exception of one resonance, the data can be fitted by assuming incoherent scattering. The distributions lead to the following assignments: 4.22 Mev, $J=3/2^+$; 4.60 Mev, $J=5/2^+$; 5.09 Mev, $J=1/2$, $(3/2)^+$; 5.14 Mev, $J=(5/2^+)$; 5.75 Mev, $J=3/2^-$; 6.14 Mev, $J=1/2$, $(3/2^+)$. The two lower levels have been identified.[1,2] Indications of spin-orbit level ordering in Al^{25} will be pointed out.

* Supported in part by the U. S. Atomic Energy Commission.
† Now at the University of Maryland, College Park, Maryland.
[1] Bartholomew, Gove, Litherland, and Paul, Phys. Rev. **99**, 1649(A) (1955).
[2] L. J. Koester, Jr., Phys. Rev. **85**, 643 (1952).

B4. Proton Groups from $Al^{27}(\alpha,p)Si^{30}$.* F. L. HASSLER, F. E. STEIGERT, AND G. F. PIEPER, *Yale University.*—The reaction $Al^{27}(\alpha,p)Si^{30}$, using 8.00-Mev cyclotron alpha particles, was studied with nuclear emulsions, proportional counters, and a scintillation spectrometer. Observations at 45°, 60°, 90°, and 152.5° with nuclear emulsions give a value for the ground-state Q value of 2.38 ± 0.03 Mev. While this value is higher than previous results, it is in good agreement with the mass value.[1] Ten additional proton groups were observed corresponding to Si^{30} excitation levels of 2.23 ± 0.02; 3.52 ± 0.02 3.80 ± 0.04; 4.83 ± 0.02; 5.28 ± 0.02; 5.52 ± 0.03; 5.94 ± 0.04; 6.52 ± 0.03; 7.10 ± 0.03; 7.38 ± 0.05 Mev. No evidence was found for the two levels at 5.07 and 5.62 Mev tenatively assigned to Si^{30} by Van Patter *et al.*[2] Although the level at 4.83 Mev was not seen by Van Patter, it has been observed previously.[3] The levels at 5.28, 5.94, 6.52, and 7.10 Mev are previously unreported. Results from the proportional counters and the scintillation spectrometer are in good agreement with the above level spacings. Angular distributions are also under study.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] P. M. Endt and J. C. Kluyver, Revs. Modern Phys. **26**, 95 (1954).
[2] D. M. Van Patter and W. W. Buechner, Phys. Rev. **87**, 51 (1952).
[3] D. E. Alburger and E. M. Hafner, Revs. Modern Phys. **22**, 373 (1950).

B5. Angular Distributions of Protons from $B^{10}(\alpha,p)C^{13}$ and $Al^{27}(\alpha,p)Si^{30}$ Reactions. P. VON HERRMANN AND G. F. PIEPER, *Yale University.*—The compound nucleus model for a nuclear reaction predicts certain angular distributions of reaction products which depend on level parameters, separation, and density. The direct interaction process suggested by Austern, Butler, and McManus[1] will also yield certain angular distributions. The distribution from a compound nucleus reaction should in general be sensitive to small changes in bombarding energy while the distribution resulting from a direct interaction should not. These experiments were performed to test for a possible indication of prevalence of one or the other process in some reactions. The angular distributions of the ground-state group from $B^{10}(\alpha,p)C^{13}$ and of the ground and first excited state groups from $Al^{27}(\alpha,p)Si^{30}$ have been measured at bombarding energies of 7.1 and 8.1 Mev. The results show in the B^{10} case that there is the possibility of a strong contribution from a direct interaction process, since the distribution changes little with energy. The distributions of both groups from the Al^{27} reaction do change strongly with energy, suggesting a predominant contribution from the compound nucleus process.

[1] Austern, Butler, and McManus, Phys. Rev. **92**, 350 (1953).

B6. Angular Distributions of Protons from $Al^{27}(n,p)Mg^{27}$.* O. E. OVERSETH, JR., *Brown University.*—Small angle distributions of reaction products are of interest in the detection of "direct interaction" processes in nuclear reactions. A study is being made of the angular distributions in the forward directions of long-range proton groups from the $Al^{27}(n,p)Mg^{27}$ reaction produced by 14.1-Mev neutrons from the Brown University Cockcroft-Walton accelerator. The protons are detected by 400μ Ilford C2 emulsions placed to record protons emitted at angles from 10° to 60° with respect to the incident neutron beam. Several proton groups are resolvable corresponding generally to previously reported levels[1] in Mg^{27}. The angular distributions of several of these groups display a definite anisotropy. The clearest angle peak so far occurring is that of the protons corresponding to the 1-Mev level, which peak in the vicinity of 40°.

* Supported in part by the U. S. Atomic Energy Commission.
[1] J. R. Holt and T. N. Marsham, Proc. Phys. Soc. (London) **A66**, 258 (1953); R. K. Haling (to be published).

B7. Angular Distributions of Protons From $Cr^{52,53}(d,p)Cr^{53,54}$.* A. J. ELWYN† AND F. B. SHULL, *Washington University, St. Louis, Missouri.*—Thin targets of Cr_2O_3, one enriched with 90% Cr^{53} another enriched with 99% Cr^{52}, were bombarded by 10-Mev deuterons. Protons corresponding to the formation of the final nucleus in its ground and various of its excited states were detected by a double proportional counter telescope. Proton energies were selected by means of aluminum foils placed in front of the counter system. Q values were measured and angular distributions of the proton groups were obtained. Comparison with Butler's theoretical curves establishes the angular momentum $l_n\hbar$ for the captured neutron, from which the spin and parity of the final nuclear state may be determined. The tentative results are given in Table I.

TABLE I.

	Q value	l_n	Final spin	Final parity
$Cr^{52}(d,p)Cr^{53}$	5.74	1	3/2	Odd
	5.17	1	1/2,3/2	Odd
	4.77	3	5/2,7/2	Odd
	3.43	1	1/2,3/2	Odd
	7.55	1	0	Even
	6.69	1	0,1,2,3	Even
	6.24	1	0,1,2,3	Even
	4.88	1	0,1,2,3	Even
	4.36	1	0,1,2,3	Even
	3.76	1	0,1,2,3	Even

* Supported in part by the U. S. Air Force through the Office of Scientific Research of the Air Force Research and Development Command.
† Shell Fellow 1954–1956.

B8. Low-Lying $T=0$ Levels in P^{30}.* L. L. LEE, JR., AND F. P. MOORING, *Argonne National Laboratory.*—The $S^{32}(d,\alpha)P^{30}$ reaction has been used to observe energy levels in P^{30}. Thin targets of FeS, SnS, and CdS have been bombarded with deuterons from the ANL electrostatic generator over an energy range from 1.6 to 2.9 Mev. Alpha-particle groups have been observed at 63° and 90° and their energies measured by magnetic analysis. The measured ground-state Q value is 4.831 ±0.013 Mev with excited states at 0.693, 1.44, and 1.97 Mev. In all cases the ground and first excited states were observed with approximately equal intensities. If isotopic spin selection rules hold, $T=1$ levels will not be observed in this reaction. The 0.693-Mev level observed here agrees very well with the 0.690-Mev γ ray observed in the $Si^{29}(p,\gamma)P^{30}$ reaction.[1] The intensity with which the level is observed seems to indicate it is not the $T=1$ level as previously suggested.[2]

*Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Endt, Kluyver, and Van der Leun, Phys. Rev. **95**, 580 (1954).
[2] Broude, Green, Singh, and Willmott, Phys. Rev. **101**, 1052 (1956).

B9. (d,p) Reactions with Kr^{78} and Kr^{80}.* N. C. BLAIS† AND W. W. WATSON, *Yale University.*—Two targets of krypton gas, one analyzing Kr^{78} 45%, Kr^{80} 51%, Kr^{82} 3.8%, and other Kr^{78} 28%, Kr^{80} 65%, Kr^{82} 6.3%, were produced by the thermal diffusion separation process. Batchwise recycling of the product of several hot-wire columns led to this enrichment. The d,p reactions for both of these samples were studied with the 4-Mev deuteron beam of the Yale cyclotron. The protons were recorded at 90° only, using Ilford C2 nuclear emulsions and with the exit foil of the target chamber stopping all protons below 5.2 Mev. Histograms have been plotted for about 3500 tracks for each gas sample. Energy calibration came from the impurity nitrogen ground-state protons. The ground-state Q values are 5.9 and 5.1 Mev for Kr^{79} and Kr^{81}, respectively. The first excited level of Kr^{79} is at 5.5 Mev, while that for Kr^{81} is at 4.6 Mev. Masses calculated from these Q values and other data are in fair agreement with mass-spectrometer values.[1]

* Supported in part by the U. S. Atomic Energy Commission.
† Socony Mobile Fellow.
[1] Collins, Johnson, and Nier, Phys. Rev. **94**, 398 (1954).

B10. Fission Modes of the Even-Even Isotopes Cm^{244} and Pu^{242}. A. B. SMITH, P. R. FIELDS, AND A. M. FRIEDMAN, *Argonne National Laboratory.*—A back-to-back ionization chamber[1] is used to determine the fission modes of carefully purified Cm^{244} and Pu^{242}. The spontaneous fission of Pu^{242} is compared with the neutron induced fission of Pu^{241}. The two processes are found to be essentially identical. The most probable fragment energies as measured in this experiment are found to be:

Isotope	Energy of light frag.	Energy of heavy frag.
Cm^{244}	104 Mev	79 Mev
Pu^{242}	103 Mev	71 Mev

An empirical expression for the total fragment energies in fission is given. It is shown to compare well with the results of this experiment and previous work.

[1] Smith, Friedman, and Fields, Phys. Rev. **102**, 813 (1956).

B11. Coincident Measurement of Fragment Velocities from Spontaneous Fission of Cf^{252}.* J. L. YARNELL, W. E. STEIN, AND H. L. SMITH, *Los Alamos Scientific Laboratory.*—The velocities of the fragments emitted in the spontaneous binary

fission of Cf^{252} have been measured by a time-of-flight method.[1] The distributions of mass and kinetic energy of the fragments before prompt neutron emission have been calculated on the basis of the conservation of mass and momentum, assuming the isotropic emission of prompt neutrons from the moving fragments. Data based on approximately 1800 fission events will be presented.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] W. E. Stein, Bull. Am. Phys. Soc. Ser. II, 1, 96 (1956).

B12. Measurement of the Ratio of the $B(E2)$ in the Electric Excitation of the First Two Levels in Odd-A Nuclei.* G. T. PAULISSEN AND B. G. GOLDRING, *M.I.T.*—There have recently been indications[1] that the Bohr-Mottelson collective model theory predicts the ratio of the $B(E2)$ for the electric excitation of the first two excited states $[B(E2, I\rightarrow I+2)/B(E2, I\rightarrow I+1)]$ in odd-A nuclei more accurately than the absolute value of any of the $B(E2)$ in either odd-A or even-even nuclei. An attempt was therefore made to measure the ratio of cascade gamma transitions $I+2\rightarrow I+1\rightarrow I$ to direct gamma transitions from the first excited level: $I+1\rightarrow I$. This method is expected to yield the ratio of the $B(E2)$ to within 20% or better in nuclei in which the branching ratio cascade/crossover is larger than unity. Preliminary results have been obtained for the following nuclei: Lu^{175}, 0.22; Hf^{179}, 0.234; Ta^{181}, 0.236; Re^{185}, 0.376; Re^{187}, 0.268.

* This work has been supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Alaga, Alder, Bohr, and Mottelson, Kgl. Danske Videnskab. Selskab. Mat.-fys. Medd. 29, 9 (1955).

THURSDAY MORNING AT 10:00

110 Sterling

(N. F. RAMSEY presiding)

Radio-Frequency Spectroscopy

C1. Bloch Equations with Diffusion Terms.* H. C. TORREY, *Rutgers University.*—The phenomenological Bloch equations in nuclear magnetic resonance are generalized by the addition of terms due to the transfer of magnetization by diffusion. The revised equations describe phenomena under conditions of inhomogeneity in magnetic field, relaxation rates, or initial magnetization. As an example, the equations are solved in the case of the free precession of magnetic moment in the presence of an inhomogeneous magnetic field following the application of a 90° pulse with subsequent applications of a succession of 180° pulses. The spin-echo amplitudes agree with the results of Carr and Purcell[1] from a random walk theory.

* Supported by the U. S. Air Force, the Rutgers Research Council, and the California Research Corporation.
[1] H. Y. Carr and E. M. Purcell, Phys. Rev. 94, 630 (1954).

C2. Double Nuclear Magnetic Resonance in Solids. L. R. SARLES AND R. M. COTTS, *Stanford University.*—The magnetic dipole interaction between two unlike nuclear species, A and B, in a solid has been investigated by observing changes in the nuclear magnetic resonance line shape of the A nuclei under conditions of simultaneous resonance of the B nuclei. The rf field causing the B transitions is relatively large and of the form $H_2\cos\omega_2 t$; the A rf field is nonsaturating. The dc magnetic field and ω_2 are fixed while the A resonance is observed by sweeping the A oscillator frequency. Magnetic-field modulation is used. The second moment of the A resonance is determined for different values of H_2 and the dc magnetic field. In annealed polycrystalline samples NaF, Na^{23}, and F^{19} are A and B, respectively. With ω_2 equal to the F^{19} Larmor frequency and H_2 large compared to the Na and F line widths, the second moment of the observed Na line is significantly decreased. Experimental results and theoretical predictions by F. Bloch will be discussed.

C3. Magnetic and Quadrupole Moments of Hf^{177} and Hf^{179}. D. R. SPECK, *University of California, Berkeley.*—The hyperfine structure in the arc spectrum of enriched isotopes of hafnium has been investigated using a Fabry-Perot interferometer with mirrors of multilayer dielectric films and a hollow-cathode cooled with liquid nitrogen. The structure of the best-resolved lines has been used for the determination of the nuclear moments of the odd isotopes. The average value for the magnetic moment of Hf^{177} obtained from four of the lines by use of the Fermi-Segrè-Goudsmit formula is $+0.61\pm0.03$ nm. Using the value for the ratio of the magnetic moments of Hf^{177} and Hf^{179} reported previously,[1] the magnetic moment of Hf^{179} is -0.47 ± 0.03 nm. All lines show large deviations from the interval rule indicating a considerable quadrupole moment. Calculations for the quadrupole moment from different lines using LS coupling wave functions do not give consistent results, but indicate that the quadrupole moments of both isotopes are approximately $+3\pm1\times10^{-24}$ cm².

[1] D. R. Speck and F. A. Jenkins, Phys. Rev. 101, 1738(L) (1956).

C4. Pure Nuclear Quadrupole Resonances in Some Group IIIb Halides. I.* S. L. SEGEL AND R. G. BARNES, *University of Deleware.*—The pure nuclear quadrupole spectra of the bromides and iodides of indium, gallium, and aluminum have been detected. In each compound, it is possible to assign the six observed frequencies to the halogen involved. This multiplicity of lines arises from the two isotopes of bromine and the two spin transitions of iodine. Of the three lines assigned to each isotope or spin transition, two lie close together with a spacing of about 1% of their resonance frequency, with a third line approximately 15% of the resonance frequency below the upper pair. Exactly the same sort of spectrum was found by Dehmelt[1] in gallium trichloride and by Ludwig[2] in indium triiodide. Field gradient asymmetry parameters derived from the two spin transitions of the iodine spectra have values of 2% for the upper pair and approximately 24% for the lower line. In addition, all of these resonances were observed to be very broad or to consist of closely spaced doublets having separations of about 40 kcps.

* Work supported by the Office of Ordnance Research, U. S. Army.
[1] H. G. Dehmelt, Phys. Rev. 92, 1610 (1954).
[2] G. W. Ludwig, J. Chem. Phys. (to be published).

C5. Pure Nuclear Quadrupole Resonances in Some Group IIIb Halides. II.* R. G. BARNES AND S. L. SEGEL, *University of Deleware.*—The nuclear quadrupole resonance spectra reported in I are interpreted in terms of a dimeric molecular structure M_2X_6. This structure is consistent with that of solid $AlBr_3$[1] and with the high degree of dimerization of all these

compounds in the vapor phase.[2] Qualitatively, one expects the inner, bridging halogens to possess the smaller coupling constant because of the effective "bond switching." The doublet character of the upper resonance and the large asymmetry parameter of the lower resonance are also consistent with this assignment. The large ionic character of these compounds ($\approx 65\%$) indicates that the principal contribution to the molecular structure will come from structure types containing doubly ionized metal atoms. But the observed ratio of bridging to nonbridging coupling constants ($\approx 80\%$) requires the inclusion of a bridge structure having positively ionized bridging halogen atoms.

* Work supported by the Office of Ordnance Research, U. S. Army.
[1] R. W. G. Wyckoff, *Crystal Structures* (Interscience Publishers, Inc., New York, 1948).
[2] N. V. Sidgwick, *Chemical Elements and Their Compounds* (Oxford University Press, New York, 1950).

C6. Pure Quadrupole Spectra of Nb^{93} in $KNbO_3$.† W. D. KNIGHT AND R. R. HEWITT, *University of California, Berkeley.*—Previously[1] the quadrupole coupling (e^2qQ) of Nb^{93} in $KNbO_3$ was determined to be 16 mc and 23 mc, respectively, in the orthorhombic and rhombohedral crystal phases; the asymmetry parameter η is zero and 0.8, respectively, for these two phases. Additional information has been obtained for the same crystal. We now report, for the tetragonal phase, $e^2qQ \sim 24$ mc and $\eta = 0$. Furthermore, e^2qQ is found to be strongly dependent on temperature in all phases, and η has a large temperature dependence in the orthorhombic phase. Approximate temperature coefficients for the quadrupole coupling are -10^{-4}, -10^{-3}, and -10^{-2} per degree centigrade, respectively, for the rhombohedral, orthorhombic, and tetragonal structures. Such behavior is consistent with the large polarizability of the Nb in the ferroelectric phases of this crystal.

† Supported in part by the Office of Naval Research.
[1] R. M. Cotts and W. D. Knight, Phys. Rev. **96**, 1285 (1954).

C7. Paramagnetic Resonance Spectrum of Fe^{3+} in a Cubic Field.* W. LOW, *University of Chicago.*—The paramagnetic resonance spectrum of Fe^{3+} has been observed at 1 and 3 cm in single crystals of MgO. The spacing of the fine structure and the angular dependence of the spectrum with the variation of the magnetic field in the 100 and 110 planes of the crystal indicate that the symmetry of the crystalline electric field about the Fe^{3+} ion is cubic. The spectrum can be accounted for with $g = 2.0036 \pm 0.0008$ and a cubic splitting at zero magnetic field of $|3a| = 548$ gauss. The cubic splitting is about 11 times larger than that of Mn ion in the same crystal, and the g factor significantly higher than in Mn. This fact and the considerable smaller g factor in Eu^{2+} and in Gd^{3+} seem to indicate that the cubic field contributes the increase in the g factor whereas the spin-orbit coupling decreases the g factor. Anomalies in the line widths of the fine structure lines were observed. The ratio of the line widths for the electronic transitions $M = 5/2 : M = 3/2 : M = 1/2$ is approximately 8.5:6.5:5. An additional narrow and intense line was observed at $g = 1.9800$ which may possibly be caused by excess oxygen or vacancies in the crystalline structure.

* This work was supported by the U. S. Atomic Energy Commission.

C8. Size Effect in the Magnetic Resonance of a Ferrite Sphere. H. J. PASSERINI AND W. S. AMENT, *Naval Research Laboratory* (introduced by G. T. Rado).—A ferrite sphere (radius a) in a dc magnetic field H is excited by a circularly polarized rf field propagating parallel to H. Our problem is to compute the sphere's magnetic dipole scattering coefficient S, taking account of the ferrite's rf tensor permeability. Superposed cylindrical wave solutions of Maxwell's equations in the ferrite are expanded in spherical vector waves to obtain relatively convenient (but unsolved) boundary condition equations for determining the scattered dipole and multipole waves. Approximating, we assume an internal field of one radial wave and one plane standing wave, scattered magnetic dipole and electric quadrupole waves, all four having "circular" polarization. The previous procedure leads to an expansion of S valid through terms of relative order a^3. To this order, S is as if the ferrite had a scalar susceptibility. When the sphere is mounted appropriately in certain microwave cavities, the cavity response is determined primarily by S and depends on a in a now calculable way. Most of our presentation deals with the a dependence of the cavity response and of the susceptibilities inferred therefrom.

C9. Ferromagnetic Resonance in Metal Single Crystals in Presence of Domain Structure.* J. O. ARTMAN, *Harvard University.*—An analysis has been made of the ferromagnetic resonances expected in metal single crystals in the presence of simple forms of domain structure. Similar effects in nonconducting ferromagnetic substances had been discussed first by Smit and Beljers,[1] and Nagamiya,[2] and later by Artman.[3] Crystals of uniaxial and cubic magnetic symmetry are considered in the present derivation. As in the previous work, the single $(\omega/\gamma) - H$ resonance characteristic branches into two corresponding to microwave excitation perpendicular or parallel to the dc field H. These multidomain resonances are related to H, saturation magnetization M, anisotropy parameter K/M, and the skin depth to domain width ratio. The low field resonance observations made on Fe by Kip and Arnold[4] are found to be consistent with the predictions of this theory. The Ni secondary resonances found by Reich[5] can also be attributed to a multidomain structure.

* Supported by the U. S. Air Force.
[1] J. Smit and H. G. Beljers, Philips Research Repts. **10**, 113 (1955).
[2] T. Nagamiya, Progr. Theoret. Phys. (Japan) **10**, 72–82 (1953).
[3] J. O. Artman, Phys. Rev. **100**, 1243(A) (1955).
[4] A. F. Kip and R. D. Arnold, Phys. Rev. **75**, 1556 (1949).
[5] K. H. Reich, Phys. Rev. (to be published) and private communication.

C10. Millimeter Wavelength Magentic Resonance in Antiferromagnetic Cr_2O_3. EDWARD S. DAYHOFF, *U. S. Naval Ordnance Laboratory, White Oak, Maryland.*—Electron spin resonance absorption has been studied in single crystals of Cr_2O_3 at wavelengths of 12 mm, 6 mm, and 4 mm for several degrees around the Curie temperature of 35°C. At each frequency the magnetic field needed for resonance dropped rapidly to zero as the temperature was reduced below the Curie temperature as found previously at 12 mm by McGuire *et al.*[1] In general, antiferromagnetic resonance can be observed over a range of temperature ΔT which is roughly proportional to the 2.5 power of the frequency. For a sample at a fixed orientation an approximately linear relation is found between ω^2 and H_0^2 for each temperature, where ω and H_0 are the corresponding angular frequency and resonant magnetic field. This is in general agreement with the theoretical predictions of Keffer and Kittel, Nagamiya, and Wangsness. Our measurements also approximately confirm the orientation dependence of H_0 and the dependence of line width on H_0 predicted by theory. The crystals used were grown by E. J. Scott of this Laboratory by the flame-fusion method.

[1] McGuire, Scott, and Grannis, Phys. Rev. **102**, 1000 (1956).

C11. Antiferromagnetic Resonance in MnF_2.† F. M. JOHNSON AND A. H. NETHERCOT, JR., *Columbia University.*—Antiferromagnetic resonance has been observed in a single crystal of MnF_2 at temperatures from 57 to 66°K and wavelengths from 2.2 to 2.6 mm. At a wavelength of 2.58 mm the temperature at which the peak absorption occurred at zero applied magnetic field was 62.3 ± 0.5°K. Further observations were made at different frequencies in this range. A magnetic field Ho variable from 0 to 9000 gauss was used to tune the resonance. Frequencies corresponding to both signs in the expression[1] $\omega/\gamma = (2H_EH_A)^{\frac{1}{2}} \pm H_0[1 - (\alpha/2)]$, were observed. The observed g value was approximately the expected value of

about two. These results are in reasonable agreement with the predictions of Keffer and Kittel[1] and of Keffer.[2] These resonances were characterized by extremely broad lines (full width approximately 7000 gauss).

† Work supported jointly by the Signal Corps, the Office of Naval Research, and the Air Research and Development Command.
[1] F. Keffer and C. Kittel, Phys. Rev. **85**, 329 (1952).
[2] F. Keffer, Phys. Rev. **87**, 608 (1952).

C12. Electron g Value in the Ground State of Deuterium.* J. S. GEIGER,† H. E. RADFORD, AND V. W. HUGHES, *Yale University.*—The ratio of the electron g_J in the deuterium ground state to the proton g_P in a cylindrical mineral oil sample has been measured. The measurement was made by the microwave magnetic resonance absorption method and apparatus which Beringer and Heald[1] used to determine g_J/g_P for hydrogen. The three strong field Zeeman transitions having $\Delta M_J=\pm 1$, $\Delta M_I=0$ were observed at a frequency of 9200 Mc/sec. The accuracy was limited by the minimum observed line widths of 20 ppm resulting principally from magnetic field inhomogeneities. Using the Breit-Rabi formula, the unweighted mean of 68 observations yields $-g_J(D)/g_P=658.2162$ with an assigned error of ± 0.0008. The ratio of this value to the value of $-g_J(H)/g_P$ obtained by Beringer and Heald,[1] who used an identical mineral oil sample, is $g_J(D)/g_J(H)=0.9999983\pm 0.0000015$, and to the value of $-g_J(H)/g_P$ of Koenig, Prodell, and Kusch,[2] after suitable diamagnetic corrections,[1] is $g_J(D)/g_J(H)=0.9999997\pm 0.0000025$. These values of $g_J(D)/g_J(H)$ are in agreement with the less precise direct measurement of Nelson and Nafe.[3]

* This research was supported in part by the Office of Naval Research.
† Yale University Sterling Fellow.
[1] R. Beringer and M. A. Heald, Phys. Rev. **95**, 1474 (1954).
[2] Koenig, Prodell, and Kusch, Phys. Rev. **88**, 191 (1952).
[3] E. B. Nelson and J. E. Nafe, Phys. Rev. **76**, 1858 (1949).

THURSDAY MORNING AT 10:00

160 Sterling

(R. B. SETLOW presiding)

X-Rays and Optical Spectroscopy

D1. Measurement of the Response of High-Energy X-Ray Detectors.* J. E. LEISS, J. M. WYCKOFF, AND H. W. KOCH, *National Bureau of Standards.*—Quantitative interpretations of most data from high-energy x-ray detectors, particularly spectrometers, require accurate pulse-height distributions produced by monoenergetic x-rays. These response distributions have been difficult to obtain above 20 Mev. A preliminary study will be described which has been used to measure the response of a 5 in. by 9 in. sodium iodide spectrometer to 33-Mev x-rays. The method consists in the unfolding of an experimental curve of counts, $\alpha(E_0,k_0)dk$, recorded in a fixed differential pulse-height bin, dk, at k_0 and produced by a synchrotron spectrum, whose peak energy, E_0, was varied from 30 to 60 Mev. The spectrum was distorted by a 180-cm carbon absorber so that the total count of transmitted photons could provide a sufficiently accurate normalization[1] of the counts in the activation curve. The desired response, $S(k,E)dk$ for a photon of energy E, can be evaluated from the activation integral $\alpha(E_0,k_0)dk=\int_0^{E_0}P(E_0,E)S(k_0,E)dEdk$ with tables[2] of the inverse of the bremsstrahlung number spectrum matrix, $P(E_0,E)$. The method can provide response functions of detectors for any given experimental arrangement.

* Supported by the U. S. Air Force, through the Office of Scientific Research of the Air Research and Development Command, and the U. S. Atomic Energy Commission.
[1] Koch, Leiss, and Pruitt, Bull. Am. Phys. Soc., Ser. II, 1, 199 (1956).
[2] A. S. Penfold and J. E. Leiss (private communication).

D2. Infrared Spectra of the Alkali Halides. II. Sodium and Potassium Halides. STUART A. RICE* AND WILLIAM KLEMPERER, *Harvard University.*—The infrared spectra of gaseous sodium and potassium halides have been measured and the vibration frequencies determined. Together with earlier studies of the lithium halides,[1] these data enable a critical evaluation to be made of the classical ionic model for these molecules as proposed by Rittner.[2] Further, when suitably combined with data from the electronic spectra, the structure of the molecules in the gaseous phase, including potential energy curves for both upper and lower states, can be determined. Evidence for, and the possible structure of, dimeric species in the gaseous phase will also be discussed.

* Junior Fellow, Society of Fellows.
[1] W. Klemperer and S. A. Rice (to be published).
[2] E. S. Rittner, J. Chem. Phys. **19**, 1030 (1951).

D3. Spectrum of Some Lithium Halides. R. STEPHEN BERRY AND WILLIAM KLEMPERER, *Harvard University.*—The ultraviolet absorption spectra of LiI, LiBr, and LiCl molecules have been observed in the quartz region. The spectra appear as continua with associated fluctuation bands extending toward the red. The separations of the bands, as in the case of other alkali halides, are in good agreement with the observed vibration frequencies.[1,2] The spectra are attributed to excitation from the highly ionic ground state to an essentially nonionic, repulsive upper state. Together with the infrared spectra[2] and reasonable assumptions about the vibrational assignments of the bands, these spectra permit characterization of the states involved in the transition.

[1] R. F. Barrow and A. D. Caunt, Proc. Roy. Soc. (London) **A219**, 122 (1953).
[2] W. Klemperer and S. A. Rice (to be published).

D4. Microwave Spectra of Gallium Chloride, Bromide, and Iodide.* M. MANDEL† AND A. H. BARRETT,‡ *Columbia University.*—The pure rotational spectra of GaCl, GaBr, and GaI have been observed using a high-temperature spectrometer.[1] Since the nuclear spins of Ga, Cl, Br, and I are $>\frac{1}{2}$, the spectra are complicated by hyperfine structure resulting from the interaction of each electric quadrupole moment with the molecular fields. Rotation, vibration-rotation interaction, and quadrupole coupling constants determined are

Molecule	B_e(Mc/sec)	α_e(Mc/sec)	r_e(A)	eqQ(Mc/sec)
$Ga^{69}Cl^{35}$	4493.73 ±0.19	23.27 ±0.12	2.2017 ±0.0001	Ga^{69} −84.7± 1.0 Cl^{35} −20 ± 2
$Ga^{69}Br^{79}$	2481.99 ±0.05	9.740 ±0.03	2.3525 ±0.0001	Ga^{69} −74 ± 5 Br^{79} 134 ± 3
$Ga^{69}I$	1706.86 ±0.05	5.667 ±0.04	2.5747 ±0.0001	Ga^{69} −66 ± 8 I −549 ±30

Interpretation of the quadrupole coupling constants in terms of ionic character and bond hybridization of these molecules will be discussed.

* Work supported jointly by the Signal Corps, the Office of Naval Research, and the Air Research and Development Command.
† Now at Bell Telephone Laboratories.
‡ Now at Naval Research Laboratory.
[1] Stitch, Honig, and Townes, Rev. Sci. Instr. **25**, 759 (1954).

D5. Electron Impact Broadening. GEORGE LANDWEHR, *Yale University.*—A quantum-mechanical calculation employing the time-dependent perturbation theory[1] has been made for

the effect of collisions of plasma electrons in the Balmer series of hydrogen. The plasma is assumed to be neutral and in a state of thermal equilibrium at a temperature where the electrons may be treated nonrelativistically. Analysis of the broadenings of the first three lines of the series leads to substantial agreement with the recent experimental findings at Kiel.[2-4] The predicted spectral intensity curves deviate from the resonance shape being slightly lower in the core and higher in the wings of the lines. The half-widths of these contours are directly proportional to the density of plasma electrons and inversely proportional to the square root of the temperature.

[1] Kivel, Bloom, and Margenau, Phys. Rev. **98**, 495 (1955).
[2] G. Jurgens, Z. Physik **134**, 21 (1952).
[3] H. Griem, Z. Physik **137**, 280 (1954).
[4] W. Henkel, Z. Physik **137**, 295 (1954).

Invited Paper

D6. The Structure of Spectral Lines. HENRY MARGENAU, *Yale University.* (30 min.)

THURSDAY AFTERNOON AT 2:00

110 Sterling

(S. MILLMAN presiding)

Invited Papers

F1. Ion Pairing in Semiconductors. HOWARD REISS, *Bell Telephone Laboratories.* (30 min.)
F2. Fast Surface States on Etched Germanium Surfaces. W. L. BROWN, *Bell Telephone Laboratories.* (30 min.)

Mostly Semiconductors

F3. Preparation of *p-n* Junctions in *n*-Type AlSb.* M. GENSER AND W. P. ALLRED, *Battelle Memorial Institute.*—It was found that a *p-n* junction can be produced in disks of *n*-type AlSb by heating the disks under reduced pressure at 800°C and higher. The *p-n* junctions produced at 800°C exhibited photovoltages up to 0.6 volt, when the junction is irradiated with a 500-watt tungsten lamp. The magnitude of the photovoltage is dependent on the length of time of heating. At higher temperatures shorter annealing times are required. Photocurrents as high as 1 milliampere per square cm have been observed on some of the junctions. The junctions have high internal resistances, probably the result of a high-resistance contact to the *p*-type surface. *p-n* junctions have also been prepared by the diffusion of zinc into *n*-type AlSb. The resistivity of the *p*-type surface can be controlled by controlling the vapor pressure of zinc over the AlSb disks. Rectification and photoeffects have been studied on these specimens. Estimates of the diffusion coefficient for zinc in *n*-type AlSb have also been made.

* This work was supported by the Wright Air Development Center, Air Research and Development Command, U. S. Air Force.

F4. Band Structure of Indium Antimonide. EVAN O. KANE, *General Electric Research Laboratory.*—The work of Fan and Gobeli[1] has indicated that the valence band maximum is very close to $k=0$ if we assume the conduction band minimum to be at $k=0$. Owing to the small band gap the conduction band will be nonparabolic. A modification of the $k\cdot p$ approach is described whereby the $k\cdot p$ interaction and the k-independent spin-orbit interaction between the three valence bands and the conduction band are taken into account exactly and the effects of other bands are considered by second-order perturbation theory. The cyclotron-resonance mass $0.013\ m_0$ is assumed for the conduction band. The valence band is qualitatively similar to germanium. The heavy holes are assumed to have a mass $0.18\ m_0$ as indicated by a number of experiments. The light holes have a mass about $0.015\ m_0$ according to the present calculations. The k-dependent spin-orbit interaction[2] gives valence band energies proportional to k. Above energies of the order 10^{-6} ev these terms should not be important. The shift in the optical absorption edge with impurity concentration is analyzed on the basis of these calculations. Agreement is considerably improved over the assumption of parabolic bands with the cyclotron mass.

[1] H. Y. Fan and G. W. Gobeli, Bull. Am. Phys. Soc., Ser. II, **1**, 111 (1956).
[2] G. Dresselhaus, Phys. Rev. **100**, 580 (1955).

F5. Effective Masses of Electrons in Indium Arsenide and Indium Antimonide. R. J. SLADEK, *Westinghouse Research Laboratories.*—When a semiconductor contains electrons of small effective mass, the distribution of these electrons in the conduction band is governed by Fermi-Dirac statistics at low temperatures. This fact permits a value of the average density-of-states effective electron mass to be determined from low-temperature electrical conductivity and Hall effect measurements on samples which have a suitable concentration of extrinsic electrons. Measurements of the electrical conductivity and Hall effect of *n*-type indium arsenide and indium antimonide have been made between 1.5°K and 300°K. Theoretical curves of the conductivity as a function of kT/ζ_0, ζ_0 is the Fermi level at absolute zero and lies in the conduction band, are calculated by assuming that $\tau\sim\epsilon^s$; τ is the relaxation time and ϵ is electron energy. Best fit of these curves to the electrical conductivity *versus* temperature data in the extrinsic range determines s and ζ_0. From ζ_0 and the conduction electron concentration, as determined from the Hall coefficient, we obtain the following effective electron masses: InAs, $m^*/m_0=0.0020\pm0.0005$; and InSb, $m^*/m_0=0.016\pm0.007$. The former result is quite unexpected; the latter agrees with other determinations.

F6. Photoemission, Photoconductivity, and Absorption of Alkali Antimonide Compounds. W. E. SPICER, *RCA Laboratories.*—The photoemission, photoconductivity, and absorption of very thin films of Na_3Sb, K_3Sb, Rb_3Sb, Cs_3Sb, and $(Na,K)_2Sb$[1] have been studied from the near infrared to the near ultraviolet. These semiconducting compounds are of interest since they form the most efficient photoemitters known. The photoconductive thresholds for the materials studied are not very different, varying over only a few tenths

of an electron volt. The average value is about 0.9 ev. The absorption measurements seem in agreement with such values. The magnitudes of the absorption coefficients in the region of the photoconductive thresholds indicate fundamental transitions. Owing to the thinness of the films, the maximum absorption does not anywhere exceed 95%; thus an examination of this fundamental absorption from 1.0 to 4.0 is possible. The photoemissive thresholds of the single alkali compounds decrease from about 2.3 to 1.5 ev in going down the periodic table from Na_3Sb to Cs_3Sb. The photoemissive threshold for $(Na,K)_3Sb$ is about 1.6 ev; this can be lowered by the evaporation of small amounts of cesium onto the photoemissive film.

[1] A. H. Sommer, Rev. Sci. Instr. **26**, 725 (1955).

F7. Evaporated CdS Photoconductors. ARTHUR BRAMLEY, *CBS Laboratories.*—Experiments are presented confirming the significant role of recombination centers in the performance of evaporated CdS films. Infrared heating for a short time had a marked effect, persisting long after the heating cycle is completed, on the rate of decay and the current-voltage characteristic at constant illumination.[1] Since the rate of recombination in semiconductors is known to be influenced by strong electric fields perpendicular to the surface of the semiconductor, a CdS film, evaporated on a glass base between two Ag electrodes, was subjected to a field of 10 kv/cm through the glass base. For a constant dc field, the photoconductivity nearly doubled for as long as the field was maintained. When a high-intensity ac field was applied for a short time in the dark, the photoconductor current could under certain conditions be increased by a large factor, but when the field was cut off, the current fell to a small fraction of its initial value. The diminished dark current value persisted for hours. However, irradiation with an intense light resulted in the dark current resuming its initial value.

[1] A. and J. Bramley, MIT Conference on Physical Electronics (March, 1956).

F8. Theory of the Interaction of Normal Modes With Electron Traps. JORDAN J. MARKHAM, *Zenith Radio Corporation.*—The Born-Oppenheimer technique has been used to find relations between the normal modes of a solid and the state of an electron in a trap. Let the modes be q_i when the trap is in the ground state and Q_i when it is in the excited state. The first-order term in an expansion causes a shift in the equilibrium position of the q's and Q's. The second results in a frequency change. Higher approximations show in general that there is no simple relation between the q's and the Q's. Using these developments, the author has been able to find relations between the thermal and optical activation energies of the trap. These relations indicate that the value for the thermal binding energy of a polaron in NaCl given by Seitz and the author is in error.[1] The corrected value is 0.34 ev. The relation of these calculations to the problem of an electron in a polar lattice will be discussed.

[1] J. J. Markham and F. Seitz, Phys. Rev. **74**, 1014 (1948).

F9. *F*-Center Wave Functions.* B. S. GOURARY AND F. J. ADRIAN, *Applied Physics Laboratory, The Johns Hopkins University.*—We have set up a Hartree-Fock equation for the wave function of the electron in an *F* center, using an extension of Löwdin's method.[1] This equation has been solved approximately by expanding the wave function in a series of cubic harmonics[2] about the center of the vacancy. The radial functions have parameters which are determined by the variational principle. The ground state has Γ_1 symmetry.[3] Optical transitions can occur to the state with Γ_4 symmetry. The dominant terms are the kinetic energy and the crystalline potential. Exchange and electronic polarization terms have been estimated to be small. Lattice distortion terms have also been examined. Preliminary results, based on the use of only one term in the cubic harmonics expansion, give fairly good agreement with experimental data on the *F*-center band in several alkali halides.

* Work supported by the Bureau of Ordnance, Department of the Navy.
[1] P. O. Löwdin, "Theoretical Investigation into Some Properties of Ionic Crystals," Dissertation, Uppsala, 1948.
[2] F. C. Von der Lage and H. A. Bethe, Phys. Rev. **71**, 612 (1947).
[3] H. A. Bethe, Ann. Physik **3**, 133 (1929).

F10. Ultraviolet Measurements on MgO.* G. H. REILING AND E. B. HENSLEY, *University of Missouri.*—A one-meter normal incidence grating vacuum monochromator has been constructed for the study of the band structure of solids. Reflectivity measurements on cleaved Norton and Missouri MgO crystals have shown structure similar to that obtained by Nelson[1] with a sharp peak at 7.5 ev and two broad peaks at 11 ev and 13.2 ev. The sharp peak at 7.5 ev has small but reproducible structure showing rises at 6.96 ev, 7.16 ev, 7.28 ev, 7.4 ev, and 7.7 ev. Room temperature measurements on thin films of MgO show an increase in absorption starting at 7.5 ev similar to that previously observed in Norton and Missouri crystals. The transmission curves show structure at 7.9 ev and 8.8 ev with a broad peak at 10.5 ev. Preliminary measurements at low temperatures show a shift to higher energies but little sharpening of the peaks. Tentative interpretation of structure will be given. The most successful MgO films were made by evaporating Mg on polished LiF plates and oxidizing the films at 600°C.

* Supported in part by the Office of Naval Research.
[1] J. R. Nelson, Phys. Rev. **99**, 1902 (1955).

THURSDAY AFTERNOON AT 2:00

Sage Hall

(E. P. WIGNER presiding)

Invited Papers on High-Energy Accelerators

G1. The Heavy-Ion Linear Accelerator. E. R. BERINGER, *Yale University.* (30 min.)
G2. The Yale Linear Electron Accelerator. H. L. SCHULTZ, *Yale University.* (30 min.)
G3. The Cambridge Six-Bev Electron Accelerator. N. F. RAMSEY, *Harvard University.* (30 min.)

Post-Deadline Papers, If Any

THURSDAY AFTERNOON AT 2:00

59 Sloane

(M. A. BIONDI presiding)

Gaseous Electronics

H1. Photodetachment Studies Using A High-Intensity Mass Analyzed Negative Ion Beam.* STEPHEN J. SMITH AND LEWIS M. BRANSCOMB, *National Bureau of Standards.*—The negative ion beam emerging from an (0.018-in. diameter) aperture in the anode of a low-pressure glow discharge tube is mass analyzed with a 90° sector magnetic field to obtain pure ion beams of low energy for photodetachment studies. The mass analyzer delivers about 75% of each mass component in a well-defined beam through three stages of differential pumping to the photodetachment reaction chamber, where the pressure is independent of source pressure. Beams up to a half-microampere at energies of about 200 ev are obtained. Resolution, limited by energy spread, is such that masses 16 and 17 are completely separated, with adjacent masses up to mass 40 at least partially resolved. The use of stopping potentials with ac detection allows measurement to a tenth of a mass unit in this range. A search for the threshold for detachment from O_2^- shows that the vertical detachment energy is well below 0.8 ev. The previously measured value of the electron affinity of atomic oxygen[1] has been verified, and preliminary studies of the electron affinity of atomic sulfur will be described.

* This work was supported in part by the Office of Naval Research.
[1] L. M. Branscomb and S. J. Smith, Phys. Rev. **98**, 1127 (L) (1955).

H2. Ionic Drift Velocities and Electron Attachment Coefficients in Oxygen.* R. GEBALLE AND D. S. BURCH, *University of Washington.*—Transient ion currents following an initiating electron pulse have been studied in oxygen over a range of pd from 7 to 26 cm mm Hg and of E/p from 9 to 50 volts/cm mm. Analysis of oscillographic records yields information regarding ionic drift velocities and the electron attachment coefficient. Three distinct and pressure-independent velocities are found. The slowest ion appears from $E/p=25$ to the highest E/p studied here and its velocity *vs* E/p curve joins that found by Varney.[1] Its low-field mobility extrapolates, however, to 1.95 cm²/volt sec instead of the 2.25 reported by Varney. The other two ions are observed over limited ranges of pd and E/p. Comparison of their extrapolated mobilities with the predictions of Langevin's theory, together with other evidence, leads to their tentative identification as O_3^- and O^-, respectively. On the assumption that previously measured values[2] of the ionization coefficient can be extrapolated to lower E/p, areas of the transients have been used to compute the attachment coefficient. It is found to vary gently in the region $10 \leqslant E/p \leqslant 25$ v/cm mm and joins at each limit with curves reported[2] previously.

* Supported in part by the Office of Ordnance Research.
[1] R. N. Varney, Phys. Rev. **89**, 708 (1953).
[2] M. H. Harrison and R. Geballe, Phys. Rev. **91**, 1 (1953).

H3. Clustering of Negative Ions in Oxygen.* D. S. BURCH AND R. GEBALLE, *University of Washington.*—Shapes of the transients described in the previous paper deviate from those predicted by use of the assumption that negative ions are formed during the initiating electron pulse and retain their identity while in transit. Discreteness and pressure independence of the observed drift velocities rule out any explanation in terms of labile clustering. The simplest explanation of the details of the transients requires stable clustering of initially formed negative ions into two slower species. On a basis of available information regarding electronic and ionic reactions in oxygen, it is suggested that the initial ions are O^- and that the clustered species are O_2^- and O_3^-. Values of coefficients that describe the clustering can be deduced by curve-fitting techniques. They are found to have orders of magnitude comparable with ionization and attachment coefficients in the same range of E/p. Their variation with E/p and pd will be discussed.

* Supported in part by the Office of Ordnance Research.

H4. Ambipolar Diffusion and Formation of Negative Ions in Oxygen Plasma. ERICH SCHULZ-DUBOIS,* *J. W. v. Goethe Universitaet, Frankfort, Germany.*—Using microwave techniques described earlier,[1] it was observed that the two forms of the oxygen plasma discovered by R. Seeliger[2] show a different behavior of the electron removal rate in the decaying plasma. Positive ion mobilities are found by analyzing the exponential part of the decay curves. The mobility measured in the decaying T form agrees with the value known for O_2^+ in O_2, indicating the ions to be O_2^+. The mobility measured in the H form is 2.5 times higher and is ascribed to O^+ ions; for the O^+ mobility is expected to be higher by about two as O^+ is not subject to charge transfer with O_2 in contrast to O_2^+. Formation of negative ions is found in the T form only. Therefore, this should take place by attachment of electrons to ozone molecules which are formed in the T form exclusively. The most probable reaction appears to be $O_3+e \rightarrow O_2+O^-+1.3$ ev.

* Present address: Raytheon Manufacturing Company.
[1] Eckhardt, Honerjaeger, and Schulz-DuBois, Z. angew. Phys. **6**, 246 (1954).
[2] R. Seeliger and A. Wichmann, Ann. Physik (6)**9**, 235 (1951).

H5. Imprisonment of Resonance Radiation in a Gaseous Discharge. P. J. WALSH, *Westinghouse Electric Corporation.*—Following the theory of Holstein,[1] the density N_r and imprisonment lifetime T of Doppler broadened resonance radiation were investigated for a gaseous discharge between parallel plates. A general solution is given. For a Maxwellian distribution of electrons two simple solutions occur according as $N_e \nu T \leqslant 1$ or $N_e \nu T \gg 1$; N_e is the electron density, ν the rate of de-excitation of resonance atoms per electron by electron collision. With $N_e \nu T \leqslant 1$, N_r can be given by a simple relation which compares well with the exact solution, and T is essentially equal to the decay time as calculated by Holstein for the decay of resonance radiation following optical excitation. For $N_e \nu T \gg 1$, N_r is given by its thermodynamic equilibrium value at the temperature of the electrons, and T falls below the decay value. Here the number of resonance photons emitted from the discharge equals that emitted from a blackbody at the temperature of the electrons in the spectral range corresponding to the "width" of the broadened line.

[1] T. Holstein, Phys. Rev. **72**, 1212 (1947); **83**, 1159 (1951).

H6. Collective Description of Electron Interactions and Electrostatic Correction to White Dwarfs. R. P. SINGH, *National Research Council, Canada.*—In the usual discussion of the equilibrium configurations of white dwarfs the mutual electrostatic attraction or repulsion between the ions and the electrons is neglected. Kothari[1] calculated this correction using the Debye-Hückel theory of strong electrolytes and con-

sidering electrons as a degenerate Fermi-Dirac gas. In this calculation the repulsion between the ions was neglected. Later Singwi[2] made more precise calculations taking the ion repulsion also into consideration. These calculations, however, do not seem to be very accurate and they can be much improved if one remembers that the electron density in a white dwarf can be very high ($\sim 10^{31}$/cc). In such a situation it will be more realistic to adopt the method of Bohm and Pines[3] and treat the electron interactions on their collective model. The Bohm-Pines method is very successful in estimating the cohesive energy of metals (electron density $\sim 10^{23}$/cc) and is much more suitable for white dwarf stars where the electron density is much higher. The calculations based on this model will be reported and compared with the results obtained otherwise.

[1] D. S. Kothari, Phil. Mag. **12**, 665 (1931).
[2] K. S. Singwi, D.Sc. thesis, University of Allahabad (1949) (unpublished).
[3] D. Bohm and D. Pines, Phys. Rev. **92**, 609 (1953).

H7. Stability of a Uniform Plasma in the Positive Column of a Glow Discharge.* HARRY S. ROBERTSON, *University of Miami.*—The ion balance equations for the positive column are examined for stability subject to small perturbations in ion concentrations. When ionization results from direct electron impact, a small perturbation of the ion concentrations decays exponentially, and the plasma may be stable. When ionization proceeds as a two-step process involving metastable excited atoms, conditions exist for which small perturbations will not remain small. The ion balance equations then become highly nonlinear and intractable. Moving striations in noble gas positive columns may be a consequence of this instability. Calculations of the characteristic waves in a positive column subject to production and loss of electrons, positive ions, and metastables, lead to an equation of 18th degree in the wave vector. This has not yet been solved. Elimination of all production, loss, and metastable terms leads to a single wave, moving in the direction of the current flow with a velocity approximately equal to the mean drift velocity of the positive ions. Qualitative agreement with experiment is obtained in regard to the effect of pressure, current, and tube radius on the frequency, velocity, and wavelength of the striations.

* Supported in part by the Office of Ordnance Research.

H8. Effect of Variable Ionic Mobility on Ambipolar Diffusion. L. S. FROST, *Westinghouse Research Laboratories.*—Recent measurements[1,2] of the mobility of noble ions in their parent gases have shown that the mobility falls with increasing field strength, becoming inversely proportional to the square root of the field at high fields. This paper will present the solution to the ambipolar diffusion problem for cylindrical geometry and with the observed field dependence of ionic mobility. Results for He^+ ions in He indicate that ambipolar diffusion in a low-pressure positive column may be reduced by a factor of four or more from that predicted using constant mobility. The theory is also applicable to Ne^+ ions in Ne and to A^+ ions in A.

[1] J. A. Hornbeck, Phys. Rev. **84**, 615 (1951).
[2] M. A. Biondi and L. M. Chanin, Phys. Rev. **94**, 910 (1954).

H9. Secondary Ion-Radical Processes in Electron Beams at Low Pressures.* DWIGHT A. HUTCHISON, *Argonne National Laboratory.*—In electron bombardment type ion sources commonly employed in mass spectrometers, electron beams of 10–50 microamps and 50–100 ev are used. It is generally assumed for the low gas pressures (10^{-6} mm Hg or less) used that the mean free path is so great that the possibility of secondary reactions is precluded. Recent measurements of ionization probability curves for He, Ne, and A have been obtained with a 60° direction-focusing mass spectrometer. The differential of the ionization probability curve reveals a peak corresponding to the ground state of the doubly charged rare gas ion. In addition, another peak appears at a potential equal to the difference between the ground states of the singly and doubly charged ions. It appears that this can be interpreted only by secondary ionization of a singly charged ion which has been electrostatically attracted back into the electron beam after the occurrence of the primary ionization act. For the molecules, H_2 and O_2, radicals and ions are formed from primary and secondary events. The resultant ion-radical reactions will be discussed.

* Based on work performed under the auspices of the U. S. Atomic Energy Commission.

H10. Production of a Beam of Metastable Helium Ions.* R. NOVICK AND E. COMMINS, *Columbia University.*—Preliminary to determination of the hyperfine splitting of the $2S_{\frac{1}{2}}$ state of ionized helium-3, a beam of metastable helium-4 ions has been produced and detected. Helium atoms are ionized and excited to the $2S_{\frac{1}{2}}$ state by electron bombardment. The ions are then drawn out of the bombardment region and accelerated to 20 volts energy. After traversing a path of 30 cm they enter a microwave cavity through which passes radio-frequency power. The radio-frequency field induces transitions to the $2P_{\frac{1}{2}}$ state, and the $2P_{\frac{1}{2}}$ ions decay almost immediately to the ground state with the emission of 303.8 A photons. These photons eject electrons from a platinum photosurface. Photodetection is used in place of surface detection in order to avoid the background signal which would result from ground-state ions. The photoelectric current is approximately 4.4×10^{-15} ampere for an ion beam current of 10^{-9} ampere and electron bombardment energy of 200 volts. These currents are of sufficient intensity and stability to permit a precise determination of the hyperfine splitting of ionized helium-3. The experiment is performed in a bakeable, stainless steel vacuum system to avoid surface charging effects.

* Supported by the Office of Naval Research, the Signal Corps, and the National Science Foundation.

H11. Excitation of the Helium Metastable Levels by Electrons. G. J. SCHULZ AND R. E. FOX, *Westinghouse Research Laboratories.*—The excitation of the metastable levels in helium (2^3S and 2^1S) was studied as a function of electron energy near threshold. The excitation due to essentially monoenergetic electrons was obtained by using the retarding potential method developed by Fox *et al.*[1] The metastables were detected by their emission of electrons from a gold-plated cylinder. It was found that the excitation function for the 2^3S level is linear from the onset of excitation to approximately 0.4 ev above onset. The excitation function peaks at 0.6 volt above the excitation threshold. A preliminary estimate for the value of the cross section of the 2^3S level is in reasonable agreement with the value given by Maier-Leibnitz.[2]

[1] Fox, Hickam, Grove, Kjeldaas, Fechter, and Rubin, Rev. Sci. Instr. **26**, 1101 (1955).
[2] Maier-Leibnitz, Z. Physik **95**, 499 (1935).

THURSDAY AFTERNOON AT 2:00

57 Sloane

(C. T. LANE presiding)

Cryogenics

I1. Electronic Specific Heat of Graphite.* W. DESORBO, *General Electric Research Laboratory,* AND J. C. BOWMAN AND J. A. KRUMHANSL, *National Carbon Company.*†—Specific heat studies (1.3° to 4.2°K) on several different graphites show a pronounced difference in this property between moderately large crystal graphites (CNG) and lampblack graphites (SA-25). Data for the former (smaller specific heat) provide strong justification for the value of electronic specific heat contribution deduced from current electronic theory, i.e., $\gamma \simeq 0.6\times10^{-3}$ cal mole^{-1} deg^{-2}. This value is in agreement with that reported by Keesom and Pearlman,[1] but it is not observed in all chemically pure graphite.[2] The γ found for SA-25 is larger than that determined for CNG by a factor of approximately 5. It is believed that this difference is not due to variations in the electronic contribution, since the data obtained on a treated CNG graphite resulting in an electronic concentration identical with SA-25 give no significant change in γ. The variation of the Hall coefficient in various doped graphites will be discussed in relation to the question of electron concentration.

* Supported in part by the U. S. Atomic Energy Commission.
† A division of Union Carbide and Carbon.
[1] P. H. Keesom and N. Pearlman, Phys. Rev. **99**, 1119 (1955).
[2] W. DeSorbo, J. Chem. Phys. **23**, 1970 (1955).

I2. Specific Heat of Gallium and Antimony. NORMAN M. WOLCOTT,* *Clarendon Laboratory, Oxford.*—The specific heats of gallium and antimony have been measured between 1° and 20°K. The electronic contribution to the specific heat for gallium is $1.8\times10^{-4}T$ cal/mole-deg, and the Debye θ at 0°K is 333°, while for antimony the electronic contribution is $1.5\times10^{-4}T$ cal/mole-deg and the Debye θ at 0°K is 204°. For both elements θ shows considerable variation with temperature below 20°K. The results are in agreement with previous measurements on gallium[1] and antimony[2] in the liquid hydrogen region. It is shown that the T^2 dependence of the specific heat for gallium does not extend below 20°K. The results are discussed with respect to the "interacting layer" model[2,3] for these elements.

* Now at the U. S. Naval Research Laboratory.
[1] Adams, Johnston, and Kerr, J. Am. Chem. Soc. **74**, 4784 (1952).
[2] W. DeSorbo, Acta Metallurgica **1**, 503 (1953).
[3] W. DeSorbo, J. Chem. Phys. **21**, 168 (1953).

I3. Superconductivity of Uranium. R. A. HEIN, W. E. HENRY, AND N. M. WOLCOTT, *Naval Research Laboratory.*—The critical magnetic field curve of a uranium specimen, high purity α phase, has been measured down to 0.37°K. The zero field transition temperature was found to be 0.68±0.02°K. Superconductivity was detected by means of a ballistic mutual inductance technique. The transition temperature is taken as that temperature at which the magnetic susceptibility departs from its normal value. The transition intervals were quite large, being spread out over 0.45°K. From the magnitude of the observed effect it may be estimated that 100% of the material went superconducting. To within experimental error the critical field data are not inconsistent with the parabolic behavior, yielding a value of 278 gauss for H_0 (critical field at absolute zero). Using this value for H_0 a value of 81.4×10^{-4} cal/mole-deg^2 is found for the electronic specific heat coefficient γ. This value is considerably smaller than the magnetic estimate of Goodman and Shoenberg,[1] but still a factor of three times larger than the calorimetric data of Smith and Wolcott.[2]

[1] B. B. Goodman and D. Shoenberg, Nature **165**, 442 (1950).
[2] P. L. Smith and N. M. Wolcott, Proceedings of the Low Temperature Physics Conference, Paris, 1955 (January, 1956, pp. 283–286).

I4. Reynolds Numbers for the Flow of Helium II. R. J. DONNELLY, *Yale University,* AND A. C. HOLLIS HALLETT, *University of Toronto.*—The results of experiments with oscillating disk systems, oscillating spheres, and oscillating U-tubes are interpreted as follows. At small amplitudes of oscillation the two fluid hydrodynamical equations are valid, and the motion of the superfluid component is irrotational. At higher amplitudes a "critical velocity" is observed, above which the normal and superfluid components move together. At any given temperature the critical Reynolds numbers corresponding to the critical velocities in all these experiments are about equal if we define the Reynolds number as the product of the maximum velocity of the boundary and the penetration depth of viscous waves, divided by the kinematic viscosity. A similar critical Reynolds number is obtained for the rotating cylinder viscometer if one replaces the penetration depth by the width of the gap between cylinders, in the expression for the Reynolds number. The choice of kinematic viscosity determines the temperature variation of the critical Reynolds number. Using the kinematic viscosity measured in a rotating bucket the critical Reynolds number is 30±20. A change to turbulent flow, unaffected by the λ transition, occurs at a Reynolds number of 250±50.

I5. Study of Boiling in Short Narrow Channels and Its Application to Design of Magnets Cooled by Liquid H_2 and N_2.* S. G. SYDORIAK AND T. R. ROBERTS, *Los Alamos Scientific Laboratory.*—A study has been made of the critical or maximum heat flux, $\dot{Q}_c$, to liquid boiling in an annular gap, of cross-sectional area, A, between a vertical cylindrical heater of height, Z, and various concentric plugs. The data are in approximate agreement with calculations based on an assumption of homogeneous and frictionless two phase flow. The pressure drop across the channel is spent primarily to accelerate the vapor being formed and the liquid carried along with it. For $\rho_V \ll \rho_L$ we find $\dot{Q}_c \doteq AL(\rho_V \rho_L f_e g Z_e)^{\frac{1}{2}}$, where L is the latent heat, ρ_V and ρ_L the vapor and liquid density, f_e the mass fraction of effluent vapor at criticality, g the gravitational acceleration, and Z_e the hydrostatic head of coolant equivalent to the pressure drop across the heater. For $Z=3$ in. or 6 in. and a channel thickness of 22 mils the ratio of observed to calculated $\dot{Q}_c$ is 0.95 for N_2 and 0.7 for H_2. The calculation is equally good for both natural convection, $Z=Z_e$, and for forced flow with Z_e up to 38 Z. Optimum copper filling factor and operating vapor pressure will be discussed for the case of

magnets cooled by natural convection boiling of various liquids. A simple roll-type coil will be shown to be superior in some respects to more conventional windings.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

I6. Comparison of He^3 Vapor Pressure Measurements with the Two 1955 He^4 Temperature Scales.* T. R. ROBERTS AND S. G. SYDORIAK, *Los Alamos Scientific Laboratory.*—Vapor pressure data for He^3 have been re-analyzed using the two proposed 1955 He^4 temperature scales: T_{55E} by Clement and T_{L55} by Van Dijk and Durieux. The temperatures corresponding to vapor pressures near 0.5°K as derived from the T_{L55} scale are less than two millidegrees lower than temperatures derived from the T_{55E} scale. The He^3 data have been fitted by a single analytical equation over the entire range from 0.45°K to the critical temperature. The equation has the form $\ln(p/T^{5/2})+i_0+(1/RT)\int_0^T S_\sigma dT=(a/T)+bT+cT^2+dT^3$. S_σ is the molar spin entropy of the liquid as discussed by Goldstein.[1] The rms deviation of temperatures corresponding to all input pressure data is about 1.5 mdeg on either temperature scale; hence, the He^3 data do not indicate a choice between the two scales.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] L. Goldstein, Phys. Rev. **96**, 1455 (1954).

FRIDAY MORNING AT 10:00

59 Sloane

(H. L. SCHULTZ presiding)

Nuclear Physics

K1. Automatic Track Following Microscope.* WILLIAM WILLIS,† *Yale University.*—A track following mechanism suitable for measuring the curvature of photographs of tracks in cloud chambers or bubble chambers has been developed. A magnified image of the track is modulated by a vibrating slit and viewed by a photomultiplier. After the resulting signal is shaped and filtered it furnishes an error signal which drives one axis of the microscope stage by means of a two phase servomotor. If the other axis is driven at constant speed, a recording instrument attached to the control axis will plot out the coordinates of the track. Tracks of minimum ionizing particles in a cloud chamber can be followed with good accuracy. Performance and applications of the instrument will be discussed.

* Supported in part by the U. S. Atomic Energy Commission.
† National Science Foundation Predoctoral Fellow.

K2. Calculations of Drift Tube Shapes for Linear Accelerators.* N. C. CHRISTOFILOS, *Brookhaven National Laboratory.*—A method is developed to determine, by numerical integration, the dimensions and shape of the drift tube in a unit cell of given length, diameter, and gap to pitch ratio. Two sets of equations are used, the first one with Bessel, Neumann, and K functions; the second one, near the axis, with Bessel functions of real and imaginary argument. The equations are expanded in four cylindrical harmonics. The constants are determined by matching the two sets along the gap at a given radius. Then, by numerical integration, the shape of the drift tube is obtained. The method is accurate since the shape is derived to conform with given equations. The resonant frequency measured in a model agrees with the predicted theoretical value within 0.1%. With the new, quasi-ellipsoidal drift tubes a constant tank diameter is possible for the 0.75 to 50 Mev Alvarez-type linac-injector for the Brookhaven alternating-gradient proton synchrotron. The length and diameter of this tank, now under design, are 110 ft and 3 ft, respectively. The drift tube diameter varies from 10 in. to 8 in., thus providing adequate space for strong-focusing quadrupole magnets. The power loss is estimated to be at least 20% less than in linear accelerators of conventional design.

* Work carried out under contract with the U. S. Atomic Energy Commission.

K3. Nuclear Emulsion Scanner.* P. V. C. HOUGH AND R. O. WINDER, *University of Michigan.*—An instrument has been constructed which will detect tracks of moderate grain density in Kodak NTB emulsion. Eight Mev protons yielding at least 10 μ of track in good focus are detected with nearly perfect efficiency. In preliminary trials no background pattern has been found which is counted as a track. The time required for the examination of one field of view leads to a predicted rate of scan of about 1 cm^2/min, at high lateral resolution. For acceptance, tracks must deviate by not more than $\pm 45°$ from a line vertical in the field of view. An image orthicon television camera presents a line-by-line video pattern to a screening circuit which eliminates pulses which could not possibly arise in a track passage. One line of video information so screened is stored in a quartz delay line and extracted for possible coincidence with pulses from the next line. A coincidence is stored in the line as a pulse of double amplitude, etc. Track measurements and recording will be discussed.

* Supported by the U. S. Atomic Energy Commission and by the Michigan Memorial Phoenix Project.

K4. Isolation of Cyclotron Beam Bunches.* JAMES DRAPER, *Brookhaven National Laboratory.*—Three methods were recently proposed[1] for employing the inherent phase bunching of a fixed frequency cyclotron beam to obtain a pulsed source of kilovolt neutrons—*viz.*, pulsed radial deflection of one bunch, pulsed radial deflection of ~7 bunches, and pulsed vertical deflection of ~10 bunches. The first of these has been applied to the BNL 60-in. cyclotron to obtain 22-Mev deuteron bursts ~10 ma high by ~0.005 μsec wide at an adjustable repetition rate presently limited to 100 cps by an inadequate pulser power supply. First, a 0.7 μsec deuteron pulse was extracted from the cyclotron arc. After the 7-μsec cyclotron acceleration time and at a selected phase of the dee voltage, a 10-kv by 0.05 μsec square voltage pulse was applied to the conventional radial deflector (which was biased 10 kv below its normal extraction voltage). Consequently, only one of the phase grouped beam bunches (8 bunches for a 0.7 μsec arc pulse with 11 mcps rf) was deflected onto the external beryllium target. The time profile of the resulting radiation was examined with a liquid scintillation detector.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] J. E. Draper, Bull. Am. Phys. Soc., Ser. II, 1, 69 (1956).

K5. Calculation of the Average Energy per Ion Pair for Protons in Hydrogen. A. DALGARNO, *The Queen's University of Belfast* AND G. W. GRIFFING, *Air Force Cambridge Research*

Center.—The average energy per ion pair (W) has been investigated for beam energies between 10 and 3000 kev in which, at the lower energies, attention must be given to capture and loss processes. The average energy per ion pair of the beam is taken to be given by $W=f(H^+)W(H^+)+f(H)W(H)+f(H^-)W(H^-)$, where $f(H^+)$, $f(H)$, and $f(H^-)$ are the fractional concentrations of the protons, hydrogen atoms, and negative hydrogen ions in the beam and $W(H^+)$, $W(H)$, and $W(H^-)$ the average energy per ion pair of each component. The cross sections used were those computed by Bates, Dalgarno, and Griffing.[1] The average energy per ion pair of the beam was found to be between 33 ev and 36 ev and only slightly energy dependent. Very surprisingly the approximation of Fano,[2] which could be extended to this case, gives essentially the same results as the exact method.

[1] Referred to in A. Dalgarno and G. W. Griffing, Proc. Roy. Soc. (London) **A232**, 423 (1955).
[2] U. Fano, Phys. Rev. **70**, 44 (1946).

K6. Positron Spectrum of Y^{88}.* W. L. Stirling and N. Goldberg, *Washington University.*—The positron spectrum of Y^{88}, which was made by bombarding strontium with 10 Mev deuterons, was studied in a double focusing beta-ray spectrometer. Comparison of our measured distribution with the theoretically predicted one leads to the conclusion that it is not a pure beta spectrum. Internal pair production of the 1.85-Mev gamma ray should yield a positron distribution with an energy end point of 0.83 Mev. These positrons were mistakenly considered to be part of the beta spectrum by previous workers who report an end point of 0.83 Mev for the beta spectrum.[1] The internal pair production distribution makes it impossible to determine the energy end point by the usual method. We have determined it from the position of the maximum of the momentum distribution to be 0.58 Mev. Since the intensity of the positrons from internal pair production is about 10% of the beta intensity and is peaked at the high-energy end, it should introduce only a small error in the determination of the position of the maximum. Subtraction of a beta distribution of energy 0.58 Mev from our experimental distribution leaves a spectrum that is in fair agreement in shape and intensity with the theoretically predicted one for internal pair production.

* Supported in part by the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Nuclear Level Schemes, T.I.D.-5300, AEC (1955).

Invited Paper

K7. Nuclear-Resonance Studies of Electron Distribution and Crystal Structure. P. J. Bray, *Brown University.* (30 min.)

Friday Morning at 10:00

57 Sloane

(A. S. Nowick presiding)

General Physics

L1. Kinetics of Chemisorption on Metal Surfaces. Gert Ehrlich, *General Electric Research Laboratory.*—With the possible exception of hydrogen, diatomic molecules physically adsorbed on a metal surface should form a reservoir from which chemisorption can occur if the sticking coefficient is less than unity. Kinetic mechanisms involving such a physically adsorbed precursor are developed, both for reaction on a uniform surface as well as for reaction at surface singularities, such as grain boundaries or lattice steps. Analysis of the rate of adsorption of nitrogen on tungsten reveals that during the initial stages, the rate of chemisorption is controlled by diffusion over the surface and that reaction occurs preferentially at heterogeneities, of atomic dimensions, which are tentatively identified with lattice steps on the surface. The influence, on the kinetics of chemisorption, of additional binding states[1] is experimentally examined for nitrogen on tungsten. At least one state is found which is significantly populated only below 200°K, and which can be associated with the physically adsorbed precursor previously postulated. At 80°K, adsorption in this state dominates and chemisorption is inhibited, as expected for chemisorption involving an activation barrier.

[1] G. Ehrlich, J. Chem. Phys. **24**, 482 (1956).

L2. Binding of Gases on a Tungsten Surface. T. W. Hickmott and G. Ehrlich, *General Electric Research Laboratory.*—The binding levels of diatomic gases on a tungsten surface have been investigated with an adsorption spectrometer; in this, desorption of gas as a function of the temperature of the surface is measured by making a tungsten filament one arm of an impedance bridge and using the filament both as adsorption sample and resistance thermometer. For nitrogen, four different levels of binding have been isolated; the experimental results obtained for the most tightly bound of these, designated as β, are presented in detail. The method of analysis of the desorption data to yield information on the kinetics of evaporation is given. It is found that nitrogen is evolved in a reaction of the second order with respect to the concentration of β, showing that in this state nitrogen has lost its molecular identity and exists as adatoms held with a binding energy of ~145 kcal/g atom on the sample studied. Evidence for the existence of other diatomic gases—CO, O_2, and H_2—in several binding states on a tungsten filament is presented.

L3. Electrostatic Charging of Polystyrene by Metal Contact and the Effect of Surface Treatment and Destaticizers.* John M. Flynn† and Selby M. Skinner, *Case Institute of Technology.*—Pure styrene monomer (without catalyst) was thermally polymerized under oxygen-free and water vapor-free conditions. A plane surface was produced on the top of the polymer disk, without contact with solid or liquid materials. All operations were performed under a lamp-grade nitrogen atmosphere. Contact was made with copper and with zinc buttons, surface prepared prior to contact for reproducibility. Initial charge values and the subsequent charge decay were measured for the untreated polymer, for polymer subjected to oxygen atmospheres for various periods of time, and to various relative humidities for various periods of time, after polymerization. Similar measurements were made for

destaticized surfaces, using two different destaticizers. The time decay curve shows some randomness from sample to sample with, however, a definite maximum and subsequent decay, the location of the maximum depending upon the treatment parameters. Destaticizer action depends not only on the chemical nature of the destaticizer, but also upon the achievement of a manner of application which insures suitable surface coverage.

* Research supported in part by the Armed Services Medical Procurement Agency.
† Now at Dow Chemical Company. This work is a part of the Ph.D. thesis of J. M. Flynn.

L4. Measurements of the Electrostatic Component of Adhesion.* JOSEPH GAYNOR† AND SELBY M. SKINNER, *Case Institute of Technology.*—Measurements have been made of the electrical charge separation accompanying the break of metal-polymethylmethacrylate-metal adhesively bonded samples. Precise techniques in the preparation of samples (to be described) yielded consistent values in relation to the breaking strength of the samples. Using the relations from the solid-state electronic theory of the electrostatic component of adhesion,[1] there have been computed the indicated values of the electrostatic component. When plotted as a function of the breaking strength of the adhesive sample, a linear relation is obtained throughout the major portion of the breaking strength range, with, however, another linear portion of considerably smaller slope in the low breaking strength range. The measured values of the electrostatic component are of an order of magnitude beginning to be significant; the indicated values represent a minimum to the range of the actual values.

* Research supported by the Aeronautical Research Laboratory, Wright Air Development Center, U. S. Air Force. This work is a part of the Ph.D. thesis of Joseph Gaynor.
† Now with General Electric Company.
[1] S. M. Skinner, J. Appl. Phys. **26**, 498 (1955); Skinner, Savage, and Rutzler, J. Appl. Phys. **24**, 438 (1953).

L5. Electrostatic Charging and Adhesion of Cylindrical Filaments.* SELBY M. SKINNER AND BRICE CARNAHAN, *Case Institute of Technology.*—The solid-state thermodynamic equations of electrical current flow of the majority carrier in dielectric materials are solved for the equilibrium case, in cylindrical coordinates. Charge transfer at or through the surfaces, and the charge distribution either within or outside the cylindrical surface are determined. Just as in the one-dimensional case previously treated,[1] the dielectric can be positively or negatively charged, depending upon the relation of the Fermi levels of the filament and its surroundings prior to contact, and the scale and magnitude of the charge distribution in the dielectric is a function of the energy gap at the interface, the scale being from the order of atomic dimensions to centimeters or larger. In addition, in this case, the thermodynamic and electrical quantities such as the total charge transferred, its distribution, the electrical field and inner potential, depend upon the radius of curvature of the interface. The adhesional stress resulting from the charge transfer (electrostatic component of adhesion) also depends upon the curvature of the filament surface. The results are applicable to the electrical charging of textile filaments, the reinforcement of plastic or elastomeric materials by fibers or metallic wires, the charging of small radio parts, during molding enamel coatings on wires, etc.

* Research supported by the Aeronautical Research Laboratory, Wright Air Development Center, U. S. Air Force. One of the authors (B.C.) acknowledges the support of a fellowship from the General Dynamics Corporation.
[1] S. M. Skinner, J. Appl. Phys. **26**, 498 (1955); Skinner, Savage, and Rutzler, J. Appl. Phys. **24**, 438 (1953); Skinner, Gaynor, and Sohl, Modern Plastics **33**, 127 (1956).

L6. Effect of the Surface Treatment of Plane and Cylindrical Glass Surfaces on the Adhesion of Polyester Resin to Glass.* N. M. TRIVISONNO, SELBY M. SKINNER, AND LIENG-HUANG LEE, *Case Institute of Technology.*—Soda lime-silicate plate glass blocks were cleaned, and, after surface treatments described in the following, were cemented together with a specially prepared polyester resin from purified materials, according to the technique developed by Moser.[1] Over thirty surface treatments before cementing were used, including various silanes, individual resins often incorporated in adhesive formulations, and other surface treating agents. Breaking strengths up to 2500 psi were obtained. The modified vinyl silanes yielded the highest breaking strengths, indicating a strong adhesion between the polyester and the treating agents. The results with the plane glass surfaces of the blocks are correlated with the flexural strengths of glass-fiber-reinforced laminates in which the glass fiber received the identical surface treatments, and therefore, qualitatively, with the adhesion to cylindrical surfaces.

* Research supported in part by the Armed Services Medical Procurement Agency.
[1] Frank Moser, ASTM Bull. **169**, 62 (1950).

L7. Differential Cross-Section Measurements of Argon Ion-Argon Atom Single Scattering.* E. N. FULS, P. R. JONES, AND E. EVERHART, *University of Connecticut.*—Differential cross sections of the scattered particles at each angle have been measured for individual collisions between argon ions and argon atoms at large angles. The angular interval ranged from 4 to 20 degrees with a resolution of one degree. Data are obtained for an energy region of 25 to 100 kev. The ion beam traversed a collision chamber which contained the target gas argon. The pressure was maintained low enough to insure that the collision products resulted from two-body interactions. The scattered particles at each angle passed through a pair of collimating holes and then through an electrostatic analyzer. A Faraday cage and secondary electron multiplier were used to detect the charge components ionized as highly as seven times as well as the neutrals in the collision products. The cross sections for argon-argon interactions ranged from 2×10^{-15} cm^2 to 7×10^{-17} cm^2 depending on the energy and angle with an accuracy of 20%. The measurements are compared with those cross sections calculated for an exponentially screened Coulomb potential energy function. Agreement of measured and calculated cross sections is excellent at 100 kev, and fair at 50 and 25 kev.

* This work was sponsored by the Office of Ordnance Research through the Watertown Arsenal Laboratories and the Springfield Ordnance District.

L8. Crystal Structure of the Solid Rare Gases.* R. U. AYRES AND R. H. TREDGOLD,† *University of Maryland.*—A number of calculations have been made attempting to show that the face-centered cubic structure should be the most stable for solid rare gases at absolute zero, since this structure is in fact observed just below the melting point in all cases except helium. However in all cases where unexceptionable quantitative results were obtained the results have been inconclusive. The effect of zero-point lattice vibrations has been studied, as well as all two-body forces and three-body terms involving dipoles alone. The present investigation concerns the next most important three-body term, arising from dipole dipole-quadrupole interactions. This would be unimportant if it were not that contributions from larger terms are very nearly the same in each lattice. In the present case there is an appreciable difference which is due to a high-order angular dependence. In fact the results favor the hexagonal lattice by an amount of the order of 1% of the lattice cohesive energy. This suggests the possibility that the hexagonal structure may indeed be stable at absolute zero, but that the cubic structure is favored at higher temperatures and is in fact "frozen in."

* Supported by the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command.
† Now at the University of Sheffield, Sheffield, England.

L9. Physical Properties of Suspensions of Small Spheres. W. S. AMENT, *Naval Research Laboratory* (introduced by G. T. Rado).—The principal scattering coefficients of one *small* spherical particle p_i of radius r_i have the general form $A_i = (r_i/\lambda)^3 G(a,b,\cdots) F(a,b,\cdots;\ a_i,b_i,\cdots)$, where $a,b,\cdots$ are the known physical properties of an ambient "fluid," $a_i,b_i,\cdots$ those of the homogeneous particle material, and $\lambda \gg r_i$ is the known wavelength in the fluid. One can determine $a_i,b_i,\cdots$ by measuring the A_i's. For a suspension S formed by randomly dispersing particles p_i in the fluid, we operationally determine corresponding properties $a',b',\cdots$ by similar measurements on small spheres p' samples from S. A self-consistent computation of the corresponding average scattering coefficients A' of p' shows that $A' = \Sigma_i A_i[1+0(r'^2\lambda^{-2})]$, the summation running over all particles in p'. It follows that

$$F(a,b,\cdots;\ a',b',\cdots) = \Sigma_j f_j F(a,b,\cdots;\ a_j,b_j,\cdots), \qquad (1)$$

where f_j is the volume fraction of particles of type j in S. Many old and some new composition laws for $a',b',\cdots$ are deduced from (1), i.e., directly from the structure of the principal spherical scattering coefficients. The generalizations and limitations of (1) are also given.

L10. Adsorption Measurements at Very Low Pressures. S. WAGENER, *Kemet Company.*—The method described previously[1] has been used for studying adsorption of carbon monoxide and nitrogen on a number of transition metals (Ba, Sr, La, Ti, Ta, Cr, Mo, W, Mn, Fe, Ni). Carbon monoxide is adsorbed by all these metals at rates higher than 1000 cm³/sec cm². Nitrogen is adsorbed at the same high rate by a group of metals found in the center columns of the periodic table, while it is adsorbed at a low rate (<1 cm³/sec cm²) by metals in the outside (second, seventh and eighth) columns. Subsequent to adsorption of nitrogen, carbon monoxide may still be adsorbed at a high rate while no appreciable adsorption of nitrogen is observed subsequent to adsorption of carbon monoxide. Adsorbed quantities increased considerably above a critical temperature of 150 to 200°C. This is believed to be due to the onset of surface migration.

[1] S. Wagener, J. Phys. Chem. **60** (April, 1956).

L11. Method of Calculation of *EC* (Energy Coefficient) Values. N. EFREMOV.—Energy coefficient (a concept introduced by Fersman) is an empirical constant representing the contribution of an element to the lattice energy of its compounds. The formula for the calculation of *EC* values for monovalent alkaline ions is

$$EC(X) = (1:K) \times 2.25,$$

where X is any monovalent alkaline ion (Li, Na, K, Rb, Cs), K is corresponding simple total number used for calculation of values of ionic radii,[1] 2.25 is constant. E.g.,

$$EC(Li^{1+}) = (1:4) \times 2.25 = 0.55,$$

$EC(Na^{1+}) = 0.55$, $EC(K^{1+}) = 0.36$, $EC(Rb^{1+}) = 0.32$, $EC(Cs^{1+}) = 0.28$. These values are in good agreement with Fersman's[2] empirical data $-EC(Li^{1+}) = 0.57$, $EC(Na^{1+}) = 0.45$, $EC(K^{1+}) = 0.36$, $EC(Rb^{1+}) = 0.33$, $EC(Cs^{1+}) = 0.29$. On the basis of the *EC* values for monovalent alkaline ions the *EC* values for other ions may be obtained as a result of a simple regularity.

[1] N. Efremov, Phys. Rev. **92**, 1081 (A), 1953.
[2] A. E. Fersman *Geochemistry* (Moscow, 1937), Vol. III, p. 92 (Russian).

L12. Progress of Work on Kinks. GEORGE ANTONOFF, *33 Tier Street, New York 64, New York.*—Kinks exist in all three states of aggregation. In 1925 I published a work on kinks in liquids. It was said that results are based on data of one author only. Twenty-five years later I resumed this work, when new figures became available. In America it was difficult to progress. I had difficulty in publishing. Three years ago on the advice of K. T. Compton, I accepted the post of Head of the Chemistry Department in Pakistan. With the help of a number of intelligent Ph.D. students I published several papers in the *Pakistan Journal of Science*, and in *The Scientist Pakistan*, available in the libraries. I showed how to make the kinks clearly visible. I also wrote a digest of my lectures, published by the University of Karachi. It develops the theory of the kinks, necessitating a radical change of our views on the structure of matter, under the title: *Introduction to Physical Chemistry—Physical Chemistry as an Exact Science.*

FRIDAY MORNING AT 10:00

110 Sterling

(K. G. McKAY presiding)

Germanium and Silicon

N1. Groetzinger effect in Germanium. N. PENTZ AND J. ARON, *Lewis Flight Propulsion Laboratory* (introduced by Benjamin Welber).—A volume photorectification (Groetzinger effect[1]) has been observed in intrinsic germanium (resistivity >60 ohm-cm). A single crystal (10×2×2 mm) was provided with ohmic current contacts (gold-antimony) on its square faces and potential probes were placed 5.5 mm apart on a 10×2 mm face on a line parallel to the current. The required light gradient was achieved by illuminating this face near one of the probes with a spot of light (1½×2 mm) having an intensity of 15 phots. The potential difference between the probes was then measured as a function of the current for both directions of current flow. It was found that, with the illumination on, the ratio of the forward to the back resistance between the probes, after correction for the zero current Dember voltage,[2] was 0.95, the direction of easy conduction being opposite to the light gradient. No asymmetry in the resistance greater than 1% appeared for the nonilluminated crystal. Results of confirmatory ac measurements will also be reported.

[1] G. Groetzinger and J. Lichtschein, Physik. Z. **38**, 292 (1937).
[2] H. Dember, Physik. Z. **32**, 554 (1931); **33**, 207 (1932).

N2. Distribution and Cross Sections of Fast States on Germanium Surafces. C. G. B. GARRETT AND W. H. BRATTAIN *Bell Telephone Laboratories.*—A theoretical treatment of the field effect, surface photovoltage and surface recombination phenomena has been carried out, starting with the Hall-Shockley-Read model and generalizing to the case of a continuous trap distribution. One concludes, using the results presented in the preceding abstract, that the fast states lying within ±0.1 v of the center of the gap have a distribution of the form $A\cosh(qv+B)$, where v is the difference in energy, measured in units of (kT/e), between the center of the gap and the state. Mean values for A, q, and B are $A = 2.2\times10^{10}$

cm^{-2}, $q=0.34$, and $B=0.6$. From the surface photovoltage measurements, one finds a value of 10^2 for the ratio (σ_p/σ_n) of the cross sections for transitions from a state into the valence and conduction bands. This implies that the fast states are largely acceptor type. On the assumption that surface recombination takes place through the fast states, the cross sections are found to be $\sigma_p \sim 4\times10^{-15}$ cm^2 and $\sigma_n \sim 4\times10^{-17}$ cm^2. The experiments do not exclude the possible existence of other, discrete fast state levels near the conduction and valence band edges.

N3. Vacuum Microbalance Experiments on the Oxidation of Germanium. S. P. Wolsky and A. B. Fowler, *Raytheon Manufacturing Company.*—A quartz microbalance capable of detecting weight differences of 0.16 microgram has been set up in an ultra-high vacuum system. Pressures of 10^{-9} to 10^{-10} mm of Hg are attainable. The kinetics of oxidation have been followed on germanium samples with total surface areas of approximately 15 square centimeters and thicknesses of 3 to 5 mils. The germanium surfaces have been prepared for the kinetic experiments by heating in vacuum for varying periods of time at temperatures near the melting point. Argon bombarded surfaces can also be studied. The oxygen uptake of baked surfaces has not been completely reproducible. Peculiar pressure rises and correspondingly large weight changes have been observed during bakeout procedures.

N4. Effect of Annealing in Various Gases on the Bulk Lifetime of Germanium. Kurt Weiser, *RCA Laboratories.*—High-resistivity germanium crystals with a carrier lifetime of about 750 μsec were annealed at 500°C in various gases. A marked increase in bulk lifetime was observed in an oxygen atmosphere containing water vapor. Under these conditions, the lifetime attained a maximum value of 1700 μsec, which decreased upon further annealing and eventually fell below the initial value. Dry oxygen, on the other hand, merely led to a very slow decrease in lifetime, and similar behavior was also found upon annealing in hydrogen, nitrogen, helium or argon in the presence of water vapor. Prolonged annealing in dry helium had no significant effect on carrier lifetime. The data have been interpreted in terms of (a) a water catalyzed surface oxidation of recombination centers which are "leached out" from the bulk, and (b) a simultaneous oxidation of the germanium, by both oxygen and water vapor, leading eventually to a decrease in lifetime. The shape of the annealing curves and additional experiments suggest that a precipitation of a germanium oxide phase in the bulk of the crystals is responsible for the eventual lowering of the lifetime.

N5. Photoeffects and Field Effects at Germanium Surfaces. W. H. Brattain and C. G. B. Garrett, *Bell Telephone Laboratories.*—Combined measurements have been made of (1) conductivity field molulation, (2) surface recombination velocity s, (3) field modulation of s, and (4) surface photovoltage. The experiments were carried out with n-type $[\lambda \equiv (p_0/n_0)^{\frac{1}{2}} = 0.34]$ and p-type $(\lambda = 17.7)$ germanium, the surface being etched and exposed to the Brattain-Bardeen cycle of gaseous ambients. Let Y be the surface potential in units of kT/e. One finds the following: (1) the range of the quantity $(Y-\ln\lambda)$ through the cycle is from $+5$ to -5 for both samples; (2) the surface recombination velocity varies by about a factor of 10 through this range, with a maximum value around $(Y-\ln\lambda)=2.5$; and (3) the surface photovoltage passes through zero at $(Y-\ln\lambda)=3$ for the n-type sample and at $(Y-\ln\lambda)=-3$ for the p-type sample. The results are analyzed in terms of the surface charge density in the space-charge region and that (denoted by Σ_s) in fast surface states. The measurements show that Σ_s is a function of Y and of Δp, the volume density of excess carriers in the body of the semiconductor. Values for the quantities $(\partial\Sigma_s/\partial Y)_{\Delta p}$ and $(\partial\Sigma_s/\partial\Delta p)_Y$, as functions of $Y-\ln\lambda$, are deduced from the experiments.

N6. Experiments on the Photomagnetoelectric effect in Germanium. T. M. Buck and F. S. McKim, *Bell Telephone Laboratories.*—The photomagnetoelectric (PME) effect in germanium has been investigated over a wide range of light intensity, in both n- and p-type material. Measurements of PME short-circuit current in conjunction with relative conductance increase agree well with van Roosbroeck's recently developed theory of the PME effect.[1] Surface recombination velocity and volume lifetime have been determined, the former with slabs of thicknesses appreciably smaller than a diffusion length, and the latter with thicker slabs having high-recombination velocity dark surfaces. The predicted large-signal behavior of ambipolar excess-carrier diffusivity is verified. The method for determining surface recombination velocity is illustrated by its application in a study of surface abrasion damage. PME determinations of volume lifetime agree well with values obtained by the photoconductivity-decay method. Increases in surface recombination velocity and volume lifetime with increasing light intensity have been observed.

[1] W. van Roosbroeck, Phys. Rev. 101, 1713 (1956).

N7. (Abstract withdrawn.)

N8. Properties of Vapor-Deposited Germanium Layers. W. C. Dunlap, Jr., J. C. Marinace, and R. P. Ruth, *General Electric Company, Syracuse.*—The properties of thin germanium layers formed by decomposition of the di-iodide upon a hot (350°C) germanium single-crystal substrate have been studied. Layers 1- to 4-mil thick were produced during several hours' time. The layers were found by x-rays to be single crystalline. Hall and resistivity measurements were made on layers deposited on Au- and Mn-doped germanium, and on layers isolated from the substrate by grinding. The layers were usually about 1–2 ohm cm n type, with a room-temperature carrier density of the order $10^{18}/cm^3$. The Hall mobility (R/ρ) was in the range 1300–2300 cm^2/volt sec. The slope of the Hall curves between 77°K and 250°C indicated that the donor levels were 0.2 ev below the conduction band. The layers were generally converted to p type by heating 1 hr at 500°C. Since the 0.2 levels were not completely ionized at the temperature of intrinsic conduction, the density of the levels could only be estimated to be in the range 10^{16}–$10^{17}/cm^3$. Two mechanisms to account for the observed properties are being studied: (1) interstitial germanium atoms are trapped in the lattice during decomposition of the iodide at the low temperatures used; (2) iodine atoms are trapped in the lattice during the decomposition process.

N9. Deformation and Fracture of Small Silicon Crystals. G. L. PEARSON, W. T. READ, JR., AND W. L. FELDMANN, *Bell Telephone Laboratories.*—Both whiskers grown from the vapor[1] and rods cut from bulk silicon were tested in bending over a range of temperature. At 25°C whiskers around 20 μ diam and 1 mm long deformed elastically up to fracture at elastic strains as high as 2.6%. The fracture strength of cut rods increased with decreasing size and was equal to that of whiskers for the same size. Over 10^8 dislocations cm^{-2} introduced by bending at 800°C did not lower the room temperature fracture strength of whiskers. At 800°C both whiskers and rods had a sharp yield point that could be recovered by aging 2 hr at 800°C; rods yielded at 0.06% strain independently of size and the whiskers at 0.26%. Whiskers bent at 800°C would yield again at 450°C while undeformed whiskers fracture below 600°C. The results suggest that (1) even the smallest specimens contained many dislocations, (2) fracture results from another defect not present in the smallest specimens, and (3) yielding is by the Cottrell mechanism, the locking impurity probably being oxygen[2] in the rods and boron in the whiskers.

[1] Pearson, Read, and Feldmann, Phys. Rev. **100**, 1251 (1955).
[2] Kaiser, Keck, and Lange, Phys. Rev. **101**, 1264 (1956).

N10. Energy Levels in Electron Bombarded Silicon. G. K. WERTHEIM, *Bell Telephone Laboratories.*—The properties of 710-kev electron-bombardment damage in silicon have been studied with the pulsed van de Graaff, bombardment-conductivity decay method.[1] Bombardments were made at 60°C on samples of such dimensions that the incident electrons lose 30% of their energy in the sample, and produce thermally stable (to 180°C), spatially homogeneous damage believed to consist largely of single vacancies and interstitials. Bombardment of *n*-type silicon produces a recombination center 0.31 ev from a band edge, with a cross section of 5.2×10^{-17} cm^2/electron-cm of bombardment at 60°C. In addition an acceptor located 0.16 ev from the conduction band is introduced with an efficiency of 0.18 acceptor/electron-cm. In *p*-type silicon a recombination center 0.24 ± 0.02 ev from a band edge is observed, having a cross section of 4×10^{-17} cm^2/electron-cm at 60°C. A donor probably due to multiple damage located 0.29 ev from the valence band is introduced with an efficiency of 0.005 donor/electron-cm. If donors and acceptors are associated respectively with interstitials and vacancies[2] which are introduced at equal rates, a second lower lying donor must be postulated.

[1] G. K. Wertheim, Bull. Am. Phys. Soc. Ser. II, 1, 128 (1956).
[2] H. M. James and K. Lark-Horovitz, Z. physik. Chem. **198**, 107 (1951).

N11. Line Broadening of an Impurity Spectrum in Silicon. DOUGLAS SAMPSON AND H. MARGENAU, *Yale University.*—Adapting an idea proposed by Fermi to explain the shifts of high-series lines in the alkali spectra under perturbation by foreign gases, the present paper develops a theory of the broadening of impurity levels in semiconductors. While in the problem of the alkalis a large valence orbit is disturbed and often destroyed by the random motion of foreign gas molecules, the same effects result in the present instance from collisions between a hole and the phonons. In detail, the broadening arises from two mechanisms: the scattering of the bound hole by the acoustic motion of the crystal atoms, and the fluctuation in polarization energy of the atoms lying between approximately hydrogen-like orbits of the hole. The former effect is dominant and accounts reasonably well for the experimental results. The calculation is applied to boron-doped silicon and yields a total zero-point broadening of 1.6 mv; this is to be compared with an experimental value of about 1 mv and the result of 3 mv obtained by Lax and Burstein.[1]

[1] M. Lax and E. Burstein, Phys. Rev. **100**, 592 (1955).

N12. Infrared Absorption of Oxygen in Silicon. H. J. HROSTOWSKI AND R. H. KAISER, *Bell Telephone Laboratories.*—Recent experiments[1] have correlated the 9 μ infrared absorption band in silicon crystals with the oxygen content. If the oxygen is assumed to be present as a Si_2O molecule, as suggested by Kaiser, Keck, and Lange, three vibrations are infrared active. A normal coordinate analysis of Si_2O shows that two of these occur at approximately 9 μ and one at a longer wavelength. The absorption bands at 9 μ and 19.4 μ observed in silicon[2] containing oxygen give an Si—O—Si bond angle of approximately 100° using force constants calculated from these absorption bands. The 9 μ band, which is more intense because of accidental degeneracy, has been used to study oxygen concentration as a function of the conditions of crystal growth and heat treatment. Rotated crystals pulled from quartz crucibles show a pronounced 9 μ absorption which disappears after heating at 1000°C. Nonrotated pulled crystals show less absorption at 9 μ while crystals prepared by floating zone techniques in vacuum or a hydrogen atmosphere are characterized by greatly reduced absorption at 9 μ in agreement with previous results.[1] At low temperatures, fine structure is observed in some samples.

[1] Kaiser, Keck, and Lange, Phys. Rev. **101**, 1264 (1956).
[2] It was first pointed out by S. Lederhandler and H. Statz (private communication) that the 9μ and 19.4μ bands were related.

FRIDAY MORNING AT 10:00

Sage Hall

(V. L. STOUT presiding)

Invited Papers (*D.E.P.*)

P1. Resolution of Atomic Structure of a Metal Surface in the Field-Ion Microscope. E. W. MUELLER, *Pennsylvania State University.* (30 min.)

P2. Permeation of Gases through Solids. F. J. NORTON, *General Electric Company.* (30 min.)

Invited Papers

P3. (a) The Infrared Spectrum of Insulin; (b) Possible Sites of the Residues on the Wrinch 48-Unit Cyclol Model. G. A. ANSLOW, *Smith College.* (30 min).

P4. Absorption and Action Spectra of Large Molecules. R. B. SETLOW, *Yale University.* (30 min.)

FRIDAY AFTERNOON AT 2:00

Sage Hall

(H. KRAYBILL presiding)

Neutrons, Beta Emitters, Mesons, Cosmic Rays

R1. High-Energy Neutrons Produced from Beryllium by 2.2-Bev Protons.* H. L. KRAYBILL, *Yale University.*—The energy spectrum of neutrons traveling forward from a 2×2×2-in. beryllium target bombarded by 2.2-Bev protons in the cosmotron has been studied by measuring momenta of isolated secondary particles ejected in the beam direction from a graphite plate and a paraffin plate present simultaneously in an expansion chamber in the neutron beam. The relative numbers of secondaries produced in carbon and in hydrogen nuclei are inferred from the paraffin-graphite difference, since the plates contained equal amounts of carbon per unit area. Preliminary results show that most of the secondaries with momenta above 1.3 Bev/c were produced in hydrogen nuclei, while practically all with momenta below 1.3 Bev/c came from carbon. If all secondaries from the hydrogen are protons, their average kinetic energy is 1.3 Bev, which represents a lower limit to the average neutron energy. These results are consistent with those of others working with the same neutrons.[1,2]

* Supported in part by the U. S. Atomic Energy Commission.
[1] Coor, Hill, Hornyak, Smith, and Snow, Phys. Rev. **98**, 1369 (1955).
[2] Fowler, Shutt, Thorndike, and Whittemore, Phys. Rev. **95**, 1026 (1954).

R2. Spectral and Spatial Distributions of the Neutrons from the Interaction of 14.1-Mev Neutrons with Tantalum.* A. H. ARMSTRONG, L. ROSEN, AND L. STEWART, *Los Alamos Scientific Laboratory.*—The cross section for the emission of neutrons as a function of neutron energy, for 14.1-Mev neutrons incident upon tantalum, has been measured at eight angles with respect to the incident neutron direction. The neutrons were generated by intercepting a molecular beam of 22-kev deuterons with a Zr−T target, the neutron flux on the scatterer being determined by counting the alpha particles from the $T(d,n)He^4$ reaction. The detectors were 200μ–$C2$ emulsions, positioned upon the periphery of a circle whose center coincided with the center of the scatterer. The detectors were shielded from the primary source by a neutron collimator made of iron and paraffin. Over the energy region 0.5 to 5 Mev, the space-integrated neutron spectrum may be represented by the relation $\sigma(E)=CEe^{-E/T}$ where $\sigma(E)$ is in millibarns/Mev, E is in Mev, $T=0.70$ Mev and C has the value 5.9. The spatial distribution of these neutrons is isotropic within 10%. The cross section for emission of neutrons of energy 5 to 12 Mev is 0.20 barn, while the spatial distribution is strongly peaked forward. These results on tantalum support the conclusions, based upon preliminary results on Bi,[1] concerning the applicability of the statistical model in the intermediate energy region.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] L. Rosen and L. Stewart, Phys. Rev. **99**, 1052 (1955).

R3. Gamma Rays Following Single-Level Neutron Capture.* R. G. BENNETT, A. E. WALTERS, H. L. SCHULTZ, W. G. WADEY, C. K. BOCKELMAN, L. ROSLER,† AND C. A. FENSTERMACHER, *Yale University.*—Using the Yale linear electron accelerator as a pulsed source of neutrons, neutron resonances have been separated on a time-of-flight basis, and the prompt γ rays resulting from single-level capture have been examined with a 2½-in. NaI(Tl) crystal and an 80-channel pulse-height analyzer. The intensity of a 560-kev γ ray, present in the spectra following capture in the 3.86 and 9.10-ev levels of In^{116}, is observed to be much lower in the spectra from the 1.46-ev level. Measurements of the absolute intensities of γ rays corresponding to known low-lying transitions have been made for the even-even nuclei Cd^{114}, Sm^{148}, Sm^{150}, and Pt^{196}. These will be compared with similar measurements for the odd-odd nuclei In^{116} and Ta^{182}.

* Supported by U. S. Atomic Energy Commission.
† National Science Foundation Predoctoral Fellow.

R4. Resonance Neutron Capture γ Rays in Heavy Nuclei.* A. E. WALTERS, C. A. FENSTERMACHER, L. ROSLER,† R. G. BENNETT, C. K. BOCKELMAN, H. L. SCHULTZ, AND W. G. WADEY, *Yale University.*—Low-energy γ rays resulting from resonant neutron capture in Gd, Dy, Er, and Hf have been studied using the experimental arrangement described in the preceding abstract. The spectra observed are interpreted to be in agreement with the Bohr-Mottelson unified model. Gd represents a situation where comparison of the observed γ-ray energies with the expected rotational pattern can be used to infer the isotope responsible for a given resonance. The 1.72-ev and 5.9-ev resonances in Dy give rise to markedly different γ-ray spectra suggesting that different isotopes are involved in these resonances. Data will also be presented for the odd-odd compound nuclei resulting from neutron capture in Rh, Ag, Au, and Ho.

* Supported by the U. S. Atomic Energy Commission.
† National Science Foundation Predoctoral Fellow.

R5. Scintillation Response of LiI(Eu) Crystals to Monoenergetic Fast Neutrons. R. B. MURRAY AND J. SCHENCK, *Oak Ridge National Laboratory.*—The scintillation response of LiI(Eu) crystals to monoenergetic neutrons in the range 0.63 to 15 Mev has been examined as a function of Li isotope concentration, europium concentration, neutron energy, and crystal temperature. At room temperature, the pulse-height spectra of those crystals containing Li^6 demonstrate a peak from the fast neutron induced $Li^6(n,\alpha)t$ reaction. The pulse-height spectrum from Li^6I(Eu) is similar to that from normal LiI(Eu) at all neutron energies studied. The thermal neutron peak has a Gaussian shape with a resolution of about 5%. The peak from fast neutrons of energies less than 6 Mev, however, is roughly rectangular; the full width at half-maximum from 5.3-Mev neutrons, for example, is 19%. On cooling the crystals below room temperature, two effects are noted. First, the scintillation efficiency increases with decreasing temperature. With a Li^6I(Eu) crystal, the pulse height of the thermal neutron peak and the 5.3-Mev neutron peak is increased by a factor of 1.7 on cooling from room temperature to −138°C. Second, the fast neutron peak assumes a nearly Gaussian shape with a resolution of 11% at −138°C.

R6. Triple Coincidence Experiments on the Decay of Sb^{124}.* E. P. TOMLINSON, *Princeton University.*—To clarify the problem of the decay of Sb^{124}, γ-γ-γ and β-γ-γ coincidence experiments are being conducted with three crystal scintillation counters and a triple fast slow coincidence circuit. The fast channels serve a coincidence circuit with a resolving time of the order of 2×10^{-8} sec. The slow channels consist of the outputs of the fast coincidence circuit and any two of three differential discriminators which define energy windows in the spectra of the three crystals. The output of the slow (approx 10^{-6} sec) coincidence circuit gates a twenty-channel pulse-height analyzer which can be switched to the output of any

one of the three crystals. With this equipment, γ-γ-γ coincidences from three NaI(Te) crystals were first investigated, with emphasis on the energy region between 0.55 and 0.75 Mev. When wide energy windows are used, results agree with those reported by Langer and Starner.[1] However, when energy windows are reduced in width, details emerge which make questionable the proper interpretation of these results. Uncertain intensity arguments are necessary in order to select the correct one of various reasonable choices for the decay scheme.

* Supported by the U. S. Atomic Energy Commission and the Higgins Scientific Trust Fund.
[1] L. M. Langer and J. W. Starner, Phys. Rev. **93**, 253 (1954).

R7. Radioactive Decay of Terbium-161. J. M. CORK, M. K. BRICE, L. C. SCHMID, AND R. G. HELMER, *University of Michigan.*—A specimen of Gd^{160} enriched from its normal 21.9% up to 95.4% was irradiated in the heavy water pile for a week. The Gd^{161} formed by neutron capture decays by beta and gamma emission with a half-life of 3.7 min to radioactive Tb^{161}. Spectrometric studies of this activity show it to decay with a half-life of 7.15 days emitting both beta and gamma rays most of which have previously not been evaluated. The gamma rays are highly converted as evidenced by some forty electron conversion lines. Using the work functions for Dy there appear to be eight gamma rays whose energies are -25.6, 27.7, 48.9, 57.3, 74.8, 78.3, 106.2, and 132.1 kev. These energies fit remarkably well in a scheme with nuclear levels at 25.6, 74.8, 104.0, and 132.0 kev. Coincidence data with the scintillation spectrometer support the proposed plan. The beta spectrum appears to be composite with a maximum energy at 540 kev for which the log *ft* is about 6.6.

R8. Charged Pion Production in Li^6 and Li^7.* E. K. GATCHELL, *University of Rochester.*†—The absolute cross section for positive and negative pions produced at 40 and 52 Mev by 240-Mev protons on Li^6 and Li^7 has been measured. Floating wire measurements were used to define the solid angle, centered about 90° to the proton beam, and the energy interval of the emitted pions. The pions were detected in a scintillation crystal telescope using pulse-height analysis to separate the pions from the background. The proton beam was measured absolutely using the $C^{12}(p,pn)C^{11}$ reaction from carbon in a 2-mil polyethylene foil attached to the target. The results at 40 Mev are $\pi^+/\pi^-=9.5$ for Li^7 and $\pi^+/\pi^-=64$ for Li^6. This observation can be qualitatively explained by the Pauli Exclusion Principle.

* Supported by the U. S. Atomic Energy Commission.
† Now at the RCA Laboratories.

R9. Pion Production in Pion-Nucleon Collisions at 240 Mev.* A. V. CREWE AND U. E. KRUSE, *The University of Chicago*, AND H. D. TAFT, *Yale University.*—The reaction $\pi^-+P\rightarrow\pi^+ +\pi^-+N$ has been investigated using the Chicago 240-Mev π^- beam. A stack of nuclear emulsions was used to detect the π^+ which were produced in a styrofoam liquid hydrogen target. The stack was of sufficient thickness to stop π^+ produced in this reaction and identification was made on the basis of the π-μ decay. Preliminary scanning results indicate a cross section between 45° and 135° in the laboratory system of less than 0.1 mb. The significance of the present result will be discussed in the light of other experiments involving pion production in pion-nucleon collisions in the 500-Mev region.[1,2]

* Research supported by a joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Blau and Caulton, Phys. Rev. **96**, 150 (1954).
[2] Blevins, Block, and Harth, Bull. Am. Phys. Soc., Ser. II, 1, 174 (1956).

R10. Observations on Slow Heavy Primary Nuclei.* HERMAN YAGODA, *National Institutes of Health.*—Emulsions flown in improved plastic balloons to an elevation of about 122 000 ft provided an opportunity to study the low energy particles of $Z\gtrsim 6$ arriving at the top of the atmosphere with $\epsilon_0\gtrsim 150$ mev per nucleon. Recoveries were made on July 18 and 19, 1955 after 7-hr plateau flights at $h=4.1$ g cm^{-2} and $\lambda=55°N$. The number of heavy primaries stopping by ionization corrected to plateau was 17.6 ± 1.1 cc^{-1} d^{-1} which is about 3.2× greater than that observed in flights reaching a 94 000-ft elevation. Preliminary measurements of the energy spectra show that on both flights an appreciable flux exists with energies less than that predicted by the geomagnetic cutoff. The two flights exhibit large variations in the M/H ratio, 1.88 ± 0.3 on the first flight and 2.98 ± 0.6 on the second made only 24 hr later. A count of stars ($\gtrsim 3$ prongs) exhibit similar fluctuations of 3750 ± 150 and 2150 ± 170 cc^{-1} d^{-1}, respectively. A giant shower initiated by a relativistic particle of $Z=23\pm3$ was observed from which 100 shower particles and 20 evaporation tracks emerge. The angular distribution of the particles in the jet suggest a total kinetic energy release of $\sim 10^{14}$ ev.

* Research supported in part by the Space Biology Laboratory of the U. S. Air Force.

FRIDAY AFTERNOON AT 2:00

110 Sterling

(H. MARGENAU presiding)

Invited Papers (*D.E.P.*)

S1. The Properties of Atomic Negative Ions. L. M. BRANSCOMB, *National Bureau of Standards.* (25 min.)

S2. Positronium Formation in Gases. VERNON HUGHES, *Yale University.* (30 min.)

S3. Elastic Cross Sections and Electron Diffusion Coefficients. S. C. BROWN, *M.I.T.* (40 min.)

S4. Breakdown in Semiconductors. K. G McKAY, *Bell Telephone Laboratories.* (30 min.)

FRIDAY AFTERNOON AT 2:00

59 Sloane

(L. W. McKEEHAN presiding)

Magnetism; Cyclotron Resonance

U1. Magnetoresistive Effects in Interstitial Carbon-Bisulfate and Carbon-Potassium Compounds.* J. F. ANDREW, A. CHABERSKI, AND S. MROZOWSKI, *University of Buffalo.*—Bisulfate ions (acceptors) were introduced into carbons by electrolytical means, and the resistance of residual compounds thus obtained investigated at room and liquid nitrogen tem-

perature. The introduction of acceptors changes the magnetoresistive effect similarly to a decrease in the heat treatment temperature. For highly graphitized samples, acceptors decrease the magnetoresistive effect, which is large and positive for this range of heat treatments. For samples heat treated to about 2400°C the acceptors lead first to a decrease and with further increase of concentration to a reversal in sign of the effect. For samples heat treated to about 2200°C acceptors first increase and then decrease the absolute value of the effect, which is negative in this range. Potassium ions (donors) were introduced from an ammonia solution. The magnetoresistive effect at room temperature for carbons heat treated to 2800°C and 2400°C first slightly increases (change corresponding to an increase in the heat treatment temperature), butsoon starts sharply decreasing with increase of the ion concentration. Thus experiments show that high magnetoresistive effect is obtained only when the Fermi level is located in the neighborhood of the corners of the zone. Some experiments were also performed at 400°C with potassium ions introduced from the vapor phase.

* Supported by the Office of Naval Research.

U2. Magnetoresistance of *n*-type Indium Antimonide.* H. P. R. FREDERIKSE AND W. R. HOSLER, *National Bureau of Standards.*—The resistance of several oriented *n*-type single crystals of InSb (current parallel to 100 or 110 axis) was measured as a function of magnetic field (transverse as well as longitudinal) at 300, 78, and 4.2°K. The impurity content ranged from 10^{15} to 2×10^{16} cm^{-3}. Magnetic fields up to 22 000 oersted were used. The resistance change appeared to be very sensitive to the position of the potential probes; irreproducible anomalies were observed which were due to disturbances of the current pattern. Measurements were therefore made with current and potential leads attached to the end surfaces. At 300 and at 80°K the pure samples showed a transverse magnetoresistance more than 10 times the longitudinal effect, indicating *spherical* energy surfaces in the conduction band. At 4.2°K all samples are degenerate. The curves of $\Delta\rho/\rho$ *vs* H show a negative magnetoresistance at low magnetic fields, a reversal at fields between 10^2 and 10^3 oersted and a slightly sinuous character up to 20 000 oersted where a slope 2 is approached. This behavior is similar to the oscillatory magnetoresistance observed in several metals and can be attributed to quantization of the electron orbits in a magnetic field. Hall measurements indicate a freeze-out of carriers at high magnetic fields.[1]

* Research supported by the Office of Naval Research.
[1] R. W. Keyes and R. J. Sladek, **100**, 1262(A) (1955).

U3. Longitudinal Magnetoresistance in the Quantum Limit. P. N. ARGYRES AND E. N. ADAMS, *Westinghouse Research Laboratories.*—A study has been made of the effect of a magnetic field on the scattering of electrons in a semiconductor with spherical energy surfaces. The theory has been applied to longitudinal magnetoresistance in the case of a very large magnetic field and low temperatures so that all conduction electrons are in the ground oscillator state. Relaxation times for phonon and ionized impurity scattering have been calculated and the corresponding mobilities for a degenerate and nondegenerate semiconductor have been derived. Contrary to the zero magnetoresistance predicted by the usual Boltzmann theory, a field dependent magnetoresistance is found. For a nondegenerate semiconductor and in the ionized impurity scattering range a negative magnetoresistance is predicted.

U4. Antiferromagnetism of a Single Crystal of NiO. J. SINGER, *U. S. Naval Ordnance Laboratory and University of Connecticut.*—The gram magnetic susceptibility (χ) of an annealed NiO single crystal (grown by E. J. Scott) was found to be isotropic and increased from $\chi=8.5\times10^{-6}$ at 77°K to a broad maximum where $\chi=12.9\times10^{-6}$ at approximately 640°K which is the Curie temperature. When the specimen was reheated and cooled slowly through the Curie point with pressure (about 1000 lb/in.^{2}) applied along a body diagonal [111] of the crystal, the susceptibility was no longer isotropic but became $\chi=10.8\times10^{-6}$ at 77°K with the magnetic field parallel to the pressure direction and $\chi=7.8\times10^{-6}$ perpendicular to this same axis. The larger value of χ parallel implies that some of the spins have shifted their direction to at least a greater component of the spin is now perpendicular to the pressure direction [111]. When this experiment is repeated using another [111] pressure axis, the susceptibility again changes in a similar manner. This pressure effect can be understood in part when one considers the lattice distortion (from cubic to rhombohedral that occurs in NiO at the Curie temperature so that it might be energetically more favorable for spins to align at some preferred angle with respect to the pressure axis.

U5. Antiferromagnetic State in the Chrome Alums. MARY C. M. O'BRIEN, *Harvard University* (introduced by J. H. Van Vleck).—The molecular field method has been applied to the magnetic interactions in the chrome alums to describe the ordered state that occurs at low temperatures, and an antiferromagnetic Curie point is predicted even in the absence of any exchange between the chromium ions. The face-centered lattice of chromium ions is composed of four sublattices, each with a direction of easy magnetization along a (111) axis. In the ordered state each sublattice is magnetised along its principal axis, and the total magnetic moment is zero. At higher temperatures the magnetic interactions between the different sublattices are treated as a molecular field so that the entropy and susceptibilities can be found as functions of the temperature and external field. The predicted critical temperature, 0.025°K, for chromium methylamine alum is a little higher than the observed one (0.015°K–0.02°K[1]), but it would be substantially reduced by a small amount of exchange of ferromagnetic sign.

[1] R. P. Hudson and C. K. McLane, Phys. Rev. **95**, 932 (1954); Beun, Steenland, De Klerk, and Gorter, Physica **21**, 767 (1955).

U6. Pulsed Magnetic Field System for Cyclotron Resonance and Magneto-Band Effects at Infrared Frequencies.* S. FONER AND H. H. KOLM, *Lincoln Laboratory.*—The maximum attainable pulsed magnetic field is limited, in principle, by the mechanical strength of the magnet coil. A coil is described which has withstood 750 kilogauss fields repeatedly (a 50% improvement over the highest fields attained previously[1–3]) and which gives promise of withstanding peak pulsed fields of one million gauss. The coil was machined in one piece from a strong, flow-resistant copper-alloy and clamped rigidly in all directions. Power is supplied directly from a bank of surge capacitors (3 kilovolts, 1800 microfarads) through a triggered spark gap. The coil can be operated at room temperature without cooling if pulsed intermittently. The field is oscillatory with a typical half-period of 150 microseconds and its amplitude is constant to within 10% over half the free volume. A $\frac{5}{16}$-inch i.d. coil provided adequate aperture for the infrared optical system. Calculations for several modified coil designs will also be described, including one for a double coil which permits both longitudinal and transverse field measurements. The measured values of field are in good agreement with calculations.

* The research reported in this document was supported jointly by the U. S. Army, Navy, and Air Force under contract with Massachusetts Institute of Technology.
[1] P. Kapitza, Proc. Roy. Soc. (London) **A115**, 658 (1927).
[2] F. Bitter, Rev. Sci. Instr. **7**, 482 (1936).
[3] H. P. Furth and R. W. Waniek, Bull. Am. Phys. Soc. Ser. II, **1**, 226 (1956).

U7. Theory of Magneto-Band Effect and Cyclotron Resonance at Infrared Frequencies.* BENJAMIN LAX AND K. J. BUTTON, *Lincoln Laboratory.*—According to the Landau model, the energy levels of holes and electrons are $E_n=(n+\frac{1}{2})\hbar\omega_c$, where $\omega_c=eH/m^*c$, m^* the effective mass and H the magnetic field. Presumably the lowest level ($n=0$) shifts by $\frac{1}{2}\hbar\omega_c$, upward for electrons, down for holes, effectively increasing the gap in semiconductors. For a degenerate valence band the zero levels are determined by coupled "effective mass" equations involving the mass parameters of the light and heavy holes.[1] The effective mass formalism should not apply when the magneto-band shift is comparable to the gap itself. The analysis leads to a combined Mathieu and harmonic oscillator equation, which is difficult to solve. A smaller shift than that of the simple Landau levels is indicated by an approximate treatment and experiments on the magneto-band effect and cyclotron resonance.[2] An analysis of such cyclotron resonance absorption in semiconductors and semimetals at high fields and infrared frequencies as a function of magnetic field is also presented for transverse and longitudinal orientation. Dimensional effects on line shape of slabs of finite thickness are discussed. Theoretical curves are also obtained for reflection experiments most suitable for metals.

* The research reported in this document was supported jointly by the U. S. Army, Navy, and Air Force under contract with M.I.T.

[1] J. M. Luttinger and W. Kohn, Phys. Rev. **97**, 869 (1955).

[2] E. Burstein and G. S. Picus, private communication; S. Zwerdling, R. J. Keyes, *et al.* (accompanying abstract).

U8. High-Speed, Sensitive Infrared Detector for Magneto-Band Effect and Cyclotron Resonance Measurements.* R. J. KEYES AND S. ZWERDLING, *Lincoln Laboratory.*—A sensitive infrared detection system that is capable of responding to fast pulses has been developed to observe magneto-band effects and cyclotron resonance produced by pulsed magnetic fields. Zinc-doped germanium at liquid helium temperature has a high proton sensitivity in the spectral region from the visible to 38 microns.[1] Although the intrinsic speed of response of this material is better than one-tenth microsecond, its high resistivity ($\sim 2\times 10^5$ ohm-cm in presence of room temperature radiation) limits the actual frequency response to that of the $R-C$ of the measuring circuitry. A special cathode follower circuit has been designed to reduce the effective lead capacitance. The frequency response of the whole system is ≈ 2 microseconds. The photosensitivity (signal/noise = 1) for a single radiation pulse is of the order of 5×10^{-10} watt at 15 microns. The detector is operated in the prebreakdown region, and its current-voltage characteristics are unusual. The design of the detector and its accompanying optical and cooling system will also be described.

* The research reported in this document was supported jointly by the U. S. Army, Navy, and Air Force under contract with M.I.T.

[1] Burstein, Davisson, Bell, Turner, and Lipson, Phys. Rev. **93**, 65 (1954).

U9. Experiments on Magneto-Band Effect and Cyclotron Resonance at Infrared Frequencies.* S. ZWERDLING, R. J. KEYES, S. FONER, H. H. KOLM, H. LIPSON, D. WARSCHAUER, AND B. LAX, *Lincoln Laboratory,* AND W. PAUL, *Harvard University.*—Pulsed magnetic fields up to about 250 000 gauss were used to produce a shift of the absorption edge (magneto-band effect) in InSb and InAs. The wavelength was decreased gradually below the edge and the transient signal transmitted during the magnetic pulse was recorded photographically. Preliminary data for InSb gave an extrapolated shift of the band edge of approximately 0.038 ev at 200 000 oe and 0.031 ev at 160 000 oe. It is known from cyclotron resonance data[1] that the mass of the electron $m^*=0.015m_0$ for InSb. This would indicate that the magneto-band shift $\Delta E<\frac{1}{2}\hbar\omega_c$ if the shift of the valence band is also considered. The preliminary observations for InAs indicate that the effect is similar, but smaller. The energy shift at 160 000 oe is of the order of 5% of the gap. Assuming similarity of InSb and InAs band structures, the speculated electron mass by proportionality is $m^*\approx 0.03m_0$. Cyclotron resonance has also been observed on the same system at about 10 μ wavelength in InSb slabs of 100 and 200 μ thickness at fields up to 300 000 oe. The characteristics of the line shape for the transmitted power correspond to that predicted theoretically. Details of the experimental arrangement and results will be presented.

* The research reported in this document was supported jointly by the U. S. Army, Navy, and Air Force under contract with M.I.T., and by Harvard University.

[1] Dresselhaus, Kip, Kittel, and Wagoner, Phys. Rev. **98**, 556 (1955); E. Burstein and G. S. Picus (private communication).

U10. X-Ray Superlattice Lines and Heteropolarity of InSb.* U. GONSER AND B. OKKERSE, *University of Illinois* (introduced by J. S. Koehler) **(this paper scheduled on Friday at speaker's request)**.—In order to study the effect of corpuscular radiation on InSb, the question was raised, if it is possible to detect superlattice lines by means of x-rays. The answer to this question was doubtful because In and Sb follow each other closely in the periodic system and have high atomic numbers. However, it appeared possible to obtain well-defined superlattice lines [(200); (600) and (222)] after reasonable exposure times (24 hours or less). Azimuthal rotation of the crystal over certain angles around the [100]- or [111]-axis results in superposing of a second reflection on the superlattice line due to multiple reflection (Renninger effect). The ratio $F_{s.l.l.}/F_{m.l.}$ (where $F_{s.l.l.}=f_{Sb}-f_{In}$ and $F_{m.l.}=f_{Sb}+f_{In}$) is found to be significantly higher than the calculated value on the basis of the free In and Sb atoms. This would indicate that, on the average, electrons which originally belonged to the In atoms, are found in the neighborhood of Sb atoms, resulting in a partial polar character of the bond.

* Supported in part by the National Academy of Sciences and the U. S. Atomic Energy Commission.

FRIDAY EVENING AT 7:00

University Dining Hall

(E. P. WIGNER presiding)

Banquet of the American Physical Society

After-dinner speakers: L. W. MCKEEHAN and E. C. POLLARD.

SATURDAY MORNING AT 9:30

110 Sterling

(P. J. BRAY presiding)

Invited Papers

V1. Electrical Properties of Plastically Deformed NaCl Crystals. A. S. NOWICK, *Yale University.* (30 min.)

V2. Interactions of Ultrasonic Waves with Electrons in Metals. R. W. MORSE, *Brown University.* (30 min.)

Solid-State Physics

V3. Dielectric Behavior of Pile Irradiated Fused Quartz. W. TOMASCH AND N. PENTZ, *Lewis Flight Propulsion Laboratory* (introduced by Benjamin Welber).—The dielectric constant and loss of fused quartz colored nearly black by irradiation in the M.T.R. reactor have been investigated. These quantities were measured as a function of frequency between 2 kc and 300 kc at temperatures of 164°C, 250°C, and 305°C with the quartz in a dry helium atmosphere to avoid surface contamination. The quartz was subsequently bleached at 520°C and a second set of identical measurements made. No change was found in the dielectric constant. The loss averaged over the frequency range decreased 10% but the same change after annealing at 520°C was observed in unirradiated samples of fused quartz. Thus, coloration does not affect the dielectric loss of quartz although such an effect has been observed in KCl.[1] The optical absorption of the colored quartz agreed with that previously reported[2]; and the dielectric constants of the specimens were in the usual range.[3]

[1] T. Suita, Phys. Rev. **94**, 1497 (1954).
[2] E. W. J. Mitchell and E. G. S. Paige, Proc. Phys. Soc. (London) **B67**, 262 (1954).
[3] A. Von Hippel, *Dielectric Materials and Applications* (The Technological Press of Massachusetts Institute of Technology, Cambridge, 1954), p. 403.

V4. Creep and Elastic Properties of Carbon Powders.* S. MROZOWSKI, *University of Buffalo.*—A study of the changes in the electrical resistance of carbon powders under pressure provides a simple and very sensitive method for investigating the creep phenomenon. At room temperature, calcined coke powders (temperature of heat treatment 900°C–1600°C) show a considerable creep with deformation logarithmically increasing with time. The variation in relative resistance $\Delta R/R$ is roughly inversely proportional to the square root of pressure. On the other hand, graphitized coke powders (heat treatments around 2400°C) show only a small initial creep, which might be due to relative displacements of particles; no change in resistance is observed after this initial period, which lasts for about 10 to 20 sec and which is slightly longer for higher columns of powder. When the pressure is released carbon powders expand, the relative volume increase being about proportional to the square root of pressure and inversely proportional to the fourth root of the particle diameter. Large locked-in lateral pressures remain in the powder; friction at the interparticle contacts leads also to hysteresis effects when the pressure is fully or partially released and applied again.

* Performed in part under the auspices of the U. S. Atomic Energy Commission.

V5. Electronic Energy Bands in Potassium.* JOSEPH CALLAWAY, *University of Miami.*—The method of orthogonalized plane waves has been applied a a calculation of energy bands in potassium. The potential was based on a self-consistent field for the K^+ ion. Different exchange potentials were used for s, p, and d states. Energy values have been calculated for 24 irreducible representations at four symmetry points, Γ, H, P, and N of the Brillouin zone. The lowest band is found to deviate in some respects from a free electron band; k^4 terms are important and departures from spherical symmetry are present. The bands are compared with those in lithium and sodium. Most of the differences of the bands between potassium and sodium can be explained in terms of increased importance of d bands in the former. Comparison of the energy bands in potassium with those calculated for other metals of the body-centered cubic structure suggests that of some features of an energy band scheme, in particular, the order of levels in a given band may be reasonably independent of the potential used.

* Supported by the Office of Naval Research.

V6. Theory of Electrical Resistivity of Alkali Metals. M. BAILYN AND H. BROOKS, *Harvard University.*—The Bardeen[1] self-consistent model for electrical conductivity has been improved in the following ways. (1) p and d components in the expansion of the cellular wave functions have been included, (2) the *umklapp* terms have been treated more carefully, (3) the lattice vibrations have been treated by the Born-von Karman method so as to include the effects of elastic anisotropy and dispersion due to the atomic nature of the lattice. Calculations have been made for all the alkalis, and include theoretical prediction of magnitude of the room temperature resistance, the variation of resistance with pressure, and the low temperature resistance. It is concluded that the observed variation of resistance with pressure cannot be explained by the present model, but must be due to a new physical effect. It is shown that *umklapp* terms are much more important at all temperatures than was formerly believed, *umklapp* terms contributing about three times more than the ordinary terms at 5°K in sodium, for example. This effect arises because of the large contribution of transverse vibration modes in the *umklapp* range. The present calculation gives the correct order of magnitude and the approximately correct temperature dependence for the low temperature resistivity, and resolves the so-called Peierls paradox.

[1] J. Bardeen, Phys. Rev. **52**, 688 (1937).

V7. Variation of Thermoelectric Power with Magnetic Field in Some Metals and Alloys. J. C. TAYLOR AND B. R. COLES,* *Carnegie Institute of Technology* (introduced by E. M. Pugh).—Sondheimer[1] has discussed the theory of the effect of a magnetic field on the absolute thermoelectric power (S) of a metal and has concluded that the change (ΔS) in this quantity should depend on the square of the ratio of the magnetic field to the resistance in zero field (ρ_0). No previous measurements on simple metals seem, however, to have been made. In a pure-metal/alloy junction (A/B), ΔS_{AB} should be closely equal to ΔS_A if $\rho_B \gg \rho_A$, and measurements at liquid nitrogen temperatures of ΔS_{AB} for copper against copper-zinc alloys of various ρ_0 show this to be the case. The experimental values of $\Delta S/S$ for copper show the expected dependence on H^2, and their magnitude, like that of magnetoresistance values for this material, is very much greater than a one-band free-electron model would predict. Preliminary results have been obtained for a number of other pure metals.

* On leave of absence from Imperial College, London, England.
[1] E. H. Sondheimer, Proc. Roy. Soc. (London) **A193**, 484 (1948).

SATURDAY MORNING AT 9:30

59 Sloane

(H. E. FARNSWORTH presiding)

General Electron Physics

W1. Electrostatic Shutter Image Converter Tube, BERNARD R. LINDEN AND PHILIP A. SNELL, *Allen B. Du Mont Laboratories, Inc.*—The simple electrostatic image converter proposed by Schagen *et al.* has been modified by the insertion of a mesh between cathode and anode to allow pulsing the tube. Design equations have been derived which will allow construction of the tube for a range of geometrical and electrical parameters. Tubes have been constructed which may be pulsed on and off with a 165-v pulse for 10 000 v between cathode and anode. With modifications in the geometrical parameters it is possible to construct a tube which may be pulsed on and off with as low as a 10-v pulse for 10 000 v between cathode and anode. The resolution of the displays obtained thus far on this type of image converter is about 700 television lines over a 4-in. diam circle. The photocathode sensitivity lies in the range of 30 to 60 μa per lumen to a light source at a color temperature of 2870°K. Owing to the fact that the photoelectrons pass through a crossover point, it has been possible to insert deflection plates which deflect the image as a whole across the phosphor viewing screen.

W2. Rotating Gun Low-Voltage Electron Accelerator.* JOHN W. PREISS, *Yale University.* —Five thousand or less volt electrons have ranges in organic materials which make them useful probes for studying spores, viruses, etc. Hutchinson[1] has used this technique with success. However, he has cited two experimental limitations. (1) Target material must be spread out in a thin layer, which means that, say, for some conventional plant virus assay requiring a microgram or more of virus, the area presented to the electron beam must be very large. (2) Charge buildup on organic material sufficient to deflect an electron beam is possible. A low-voltage electron accelerator which will defeat these limitations is under construction. Four electron guns are mounted on a rotating bar at different radii so that they may be rotated at several speeds over concentric rings of samples, the outer of which has about a 1-ft radius. The whole assembly is mounted inside a 28-in. diam cylindrical vacuum chamber, the bottom of which can readily be removed. Target to electron gun distance is adjustable. Acceleration and filament voltage is introduced through the hollow drive shaft.

* Supported by the John A. Hartford Foundation.
[1] Franklin Hutchinson, Ann. N. Y. Acad. Sci. **59**, 494 (1955).

W3. New Ultra-High-Vacuum Ionization Gauge. J. M. HOUSTON, *General Electric Research Laboratory.*—A new ultra-high-vacuum ionization gauge will be described which is useful in the pressure range 10^{-8} to 10^{-11} mm and probably to much lower pressures (e.g., 10^{-14} mm). An ion current 60 times that of a Bayard-Alpert ionization gauge (at the same pressure) is obtained, even though the filament emission is less than 10^{-8} amp (i.e., less than one-millionth of that used in a Bayard-Alpert gauge). Average electron trajectories of approximately 10^8 cm are obtained. The pumping speed of the new gauge for helium is 0.06 liter/sec, which is approximately 15 times that of a Bayard-Alpert gauge. Attempts (now underway) to determine the low-pressure limit of the new gauge by producing very low pressures will be described.

W4. Electron Optical Study of Gas Flow at Extremely Low Pressures.* L. MARTON, D. C. SCHUBERT, AND S. R. MIELCZAREK, *National Bureau of Standards.*—Improvements in the electron-optical Schlieren apparatus for the study of low-pressure gas dynamics[1] have increased the contrast of photographs of a cadmium atomic beam at a density corresponding to 10^{-4} mm pressure. In a typical exposure the light transmission through the emulsion in background regions is less than half that found in the center of the beam. To secure maximum contrast a decelerating field was interposed between the Schlieren stop and the post-acceleration field. The decelerating field provides a barrier to secondary electrons produced by the Schlieren stop, while acting only as a weak lens to the electrons which form the Schlieren image. Photodensitometer comparisons of plates exposed in the presence and in the absence of the atomic beam indicate that the general background can be readily discounted, thus providing traces of the beam profile with reproducibility better than 5%. The application of this technique to determination of the spatial distribution and velocity distribution of gas molecules reflected from a solid surface will be discussed.

* Work supported by the Office of Naval Research.
[1] Marton, Schubert, and Mielczarek, J. Appl. Phys. **27**, 419 (1956).

W5. Penetration of Electrons in Aluminum Oxide Films. J. R. YOUNG, *General Electric Research Laboratory.*—The practical range of low-energy electrons in thin Al_2O_3 films has been measured. Films ranging in thickness from 85 to 5000 A were investigated. Results are in close agreement with the predictions of Bethe and the results obtained by Hoffman for 1000–3000 A Al_2O_3 films. The practical range-energy relation obtained was found to be $R=0.0115E^{1.35}$ where R is expressed in mg/cm^2 and E in kev.

W6. On the Origin of the Characteristic Energy Losses of Electrons in Solids. E. J. STERNGLASS, *Westinghouse Research Laboratories.*—Evidence is presented that the characteristic energy losses of electrons[1] may be explained in terms of the ionization and excitation of the outer atomic shells according to the Bohr-Bethe theory for the stopping of charged particles. The principle loss, found to occur for all substances between 12–22 ev, is interpreted as representing ionization of the bound shell next to the valence level. This process gives rise to a characteristically asymmetric peak of the same form as the known energy distribution for the secondary electrons formed in such a collision. The one or two weaker lines below 12 ev are considered to represent excitation and ionization of the valence electrons. According to the present hypothesis, these are the only basic loss processes involved, and all peaks at energies >22 ev must represent multiple collisions leading to combinations of the fundamental losses. Since these are statistically independent, their relative intensities must obey a Poisson distribution law with a collision probability calculated from the Bohr-Bethe theory. These predictions are found to be in satisfactory agreement with the available data. The suggested mechanism accounts for the similarity of the energy losses in metals and insulators and leads to the expectation of similar energy spectra for metal vapors.

[1] See the review article by Marton, Leder, and Mendlowitz, Advances in Electronics **7**, 183 (1955).

W7. Electroluminescence Decay. W. A. THORNTON, *General Electric Research Laboratory.*—Electroluminescence intensity of phosphor layers decreases with running time; this decay can be described by the empirical expression

$L=L_0/(1+t/t_4)$, where t_4 is the time to half-intensity, as pointed out by Roberts.[1] In binderless phosphor layers, the following measurements have been made as decay of light output progresses: (1) photoluminescence, (2) dark capacitance, (3) dark conductivity, (4) photoconductivity, (5) light output wave form. Also, (6) decay at 80°K was observed to proceed at an apparent rate at least 50 times slower than that at room temperature. Photoluminescence remains constant, capacitance and conductivity decrease roughly in proportion to light output, and the wave form shows several marked progressive changes. These observations can be interpreted, partly on the basis of previous work,[2] as indicating donor depletion with time. A quantitative expression describing depletion by electrolysis is presented as a likely means of correlating the foregoing observations and empirical relation.

[1] S. Roberts, unpublished work.
[2] W. A. Thornton, Phys. Rev. **102**, 38 (1956).

W8. Temperature Dependence of the Conduction Current from Plexiglas.* R. J. MUNICK, *Argonne National Laboratory.*—Transient electric currents from Plexiglas are produced either by changes in the difference of electrical potential across the specimen or by changes in the temperature of the specimen. The conduction current is observed unobscured by these transients when the temperature and the voltage are maintained constant for a sufficient period of time. Measurements were made of the conduction current at temperatures from 21 to 90°C and were found to be represented by the sum of two exponentials rather than by a single exponential, as previous results had indicated.[1] The lower temperature part, which has the smaller activation energy, agrees with the previous results. The values of conductivity range from 3×10^{-20} to 8×10^{-15} mho per cm.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] R. J. Munick, Phys. Rev. **100**, 1256(A) (1955).

SATURDAY MORNING AT 9:30

57 Sloane

(G. BREIT presiding)

Theoretical Physics

X1. On the Calculation of Molecular Orbitals. B. SEGALL, *General Electric Research Laboratory.*—The molecular-orbital problem is formulated using a variation-iteration approach. That is, a variational principle based on the integral equation for the molecular orbital is established.[1] While this approach is quite general and lends itself to an application of the Rayleigh-Ritz technique, the integrals involved are difficult to evaluate for an arbitrary potential. If, however, the molecular potential can reasonably be approximated by a potential which is spherically symmetric within spheres about the nuclei and constant outside the spheres, the approach leads to a practical and accurate method for obtaining the energies and wave functions of the individual electron states. Deviations from the approximating potential could be treated by perturbation theory. For any but the simplest molecules, the results obtained from this method are expected to be more accurate than those that can be obtained from a feasible application of the LCAO method. Besides making the calculations for fairly complicated molecules feasible, the method has the advantage that a large part of the labor involved is in the calculation of certain potential-independent constants—the "molecular structure constants"—which are characteristic of the geometrical structure.

[1] For a similar approach in the study of the band structure of solids, see W. Kohn and N. Rostoker, Phys. Rev. **94**, 1111 (1954), and B. Segall, Bull. Am. Phys. Soc., Ser. II, 1, 33 (1956).

X2. Theory of the Zeeman Effect. F. R. INNES, *Air Force Cambridge Research Center,* AND C. W. UFFORD, *University of Pennsylvania.*—In two papers[1] Abragam and Van Vleck and Kambe and Van Vleck have treated the expectation value of the Hamiltonian operator pertaining to relativistic and diamagnetic corrections. The g values for the $1s^22s^22p^4\ ^3P_1$ and $^3P_2$ levels of atomic oxygen were found and compared with the experimental values of Rawson and Beringer. We have expanded the Hamiltonian in spherical tensor operators with a view to making applications to other atomic systems as simple as possible. Some of the operators in the Hamiltonian have nonvanishing matrix elements involving both closed shell and valence electrons, and general methods for handling these elements have been developed. The results of this work, applied to the oxygen atom, are in substantial agreement with those of Kambe and Van Vleck. However, the small differences which have been found give a value for the difference of the g-value corrections which is closer to the experimental results than was found previously.

[1] A. Abragam and J. H. Van Vleck, Phys. Rev. **92**, 1448 (1953); K. Kambe and J. H. Van Vleck, Phys. Rev. **96**, 66 (1954).

X3. Nuclear Excitation by Electrons. H. R. ROBL, *Office of Ordnance Research, U. S. Army** (introduced by Sherwood Githens, Jr.).—The cross section of nuclear excitation which results from electron bombardment has been calculated, regarding this process as the inverse of electron scattering which results from nuclear transitions to lower energy states. The calculations do not make explicit use of nuclear matrix elements, but involve only the mean lifetime of the excited states. No special model having been used for the description of the nuclei, the treatment is valid for one-particle transitions as well as for collective transitions. The differential and total cross sections have been calculated for magnetic and electric transitions of arbitrary order. The cross sections are found to be inversely proportional to the mean lifetime of the excited states. The angular distribution of the photons which are emitted from the excited nuclei is predicted. Numerical results are presented for electric and magnetic dipole and quadrupole transitions assuming an electron energy of 10 mc^2 and for transition energies between 0.2 and 5 mc^2.

* On leave of absence from the University of Vienna, Austria.

X4. Magnetic Moment of a Bound Electron. P. G. FISCHER* AND A. V. BUSHKOVITCH, *St. Louis University.*—Relativistic corrections to the total electron moment, including radiative contributions, are considered, analogous to the known corrections for a Dirac particle[1,2]; the form of the correction terms is different for the anomalous and normal parts of the moment. This effect has been ignored previously,[3,4] but the change in the theoretical value of the bound-state moment is of lowest order $Z^2\alpha^3$, beyond the present experimental limit. The results are

given for the $2S_{\frac{1}{2}}$, $2P_{\frac{1}{2}}$, and $2P_{\frac{3}{2}}$ states of hydrogen, and the significance of the result is discussed.

* Present address: McDonnell Aircraft Corporation, St. Louis, Missouri.
[1] G. Breit, Nature **122**, 649 (1928).
[2] N. F. Mott and H. S. W. Massey, *Theory of Atomic Collisions* (Oxford University Press, New York, 1950), second edition, p. 71.
[3] Koenig, Prodell, and Kusch, Phys. Rev. **88**, 191 (1952).
[4] R. Beringer and M. A. Heald, Phys. Rev. **95**, 1474 (1954).

X5. Virtual States in Transfer Reactions.* G. BREIT AND M. E. EBEL, *Yale University.*—In unpublished calculations of Breit and Ebel,[1] an analysis of the data of Zucker and collaborators on low-energy yields and angular distributions of $N^{14}(N^{14},N^{13})N^{15}$ and $N^{14}(N^{14},C^{13})O^{15}$ has been made on the basis of nucleon tunneling. The calculations are in qualitative disagreement with experiment. It is pointed out that the long range of the Coulomb potential makes it possible for one N^{14} to have its internal energy raised by the electric field of the other so that the nucleon can be transferred more readily in distant collisions. This process gives appreciable factors in the direction required by experiment. Comparison with quantum calculation shows that a classical calculation of the motion of the N^{14} nuclei supplemented by a picture of borrowing excitation energy from the kinetic energy of the nitrogens gives a fair approximation to the process.

* This research was supported by the U. S. Atomic Energy Commission under Contract AT(30-1)-1807 and by the Office of Ordnance Research, U. S. Army.
[1] G. Breit and M. E. Ebel, Phys. Rev. (to be published); Gregory Breit, Bull. Am. Phys. Soc., Ser. II, 1, 162 (1956).

X6. Calculation of Nucleon Tunneling in $N^{14}+N^{14}$ Reactions Using Adiabatic Functions.* M. E. EBEL, *Yale University.*—The probability of nucleon tunneling in reactions of the type $N^{14}(N^{14},N^{13})N^{15}$ and $N^{14}(N^{14},C^{13})O^{15}$ has been calculated using adiabatic wave functions constructed by the well-depth eigenfunction method proposed by Breit.[1] In this method the wave function is expanded in eigenfunctions of the integral equation equivalent to the Schroedinger equation for one particle in the field of two potential wells. Time-dependent perturbation theory was applied to obtain the probability of transfer in the semiclassical approximation. This procedure is applicable only if the perturbation treatment converges rapidly, which is true only if resonance effects in the transfer do not enter. In this case the results were found to be equivalent to those obtained in the more detailed considerations of the energy matrix method.[2]

* This research was supported by the U. S. Atomic Energy Commission under Contract AT(30-1)-1807 and by the Office of Ordnance Research, U. S. Army.
[1] Gregory Breit, Phys. Rev. (to be published).
[2] G. Breit and M. E. Ebel, Phys. Rev. (to be published).

X7. Nucleon-Nucleon Spin-Orbit Forces in N^{15} and O^{17}.* C. A. PEARSE, *Yale University.*—The spin-orbit splitting is given for Wigner, Majorana, and Heisenberg nucleon-nucleon potentials for a nucleon outside closed shells and for a "hole" in a closed shell. The spin-orbit forces are those derived from relativistic invariance by Breit.[1] These expressions have been evaluated using Gaussian wave functions and potentials. The wave-function parameters are chosen by the alternative criteria: binding energy of last neutron, Coulomb energy of mirror nuclei, electron scattering and mu-mesonic atom experiments. The parameters a^W, a^M, and a^H are found to be about 10 for $p_{\frac{1}{2}}-p_{\frac{3}{2}}$ of N^{15} and about 20 for $d_{\frac{3}{2}}-d_{\frac{5}{2}}$ of O^{17}. These values are compared with those of Breit and Stehn[2] for $p_{\frac{1}{2}}-p_{\frac{3}{2}}$ of Li^7. Effects of shape and range parameter uncertainties and perturbations will be discussed. Exchange integral contributions are non-negligible; hence, the usual equivalent one-body spin-orbit force is inapplicable in these cases.

* This research was supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.
[1] Gregory Breit, Phys. Rev. **51**, 248 (1937).
[2] G. Breit and J. R. Stehn, Phys. Rev. **53**, 459 (1938).

X8. Analysis of Feshbach-Loman *p-p* Fits.* ALVIN M. SAPERSTEIN, *Yale University.*—Departing from the static potential formalism, Breit and Bouricius[1] fit the low energy *p-p* data using a constant boundary condition on the wave function in the $^1S_0$ state and pointed out that the boundary condition could be a representation of the velocity dependent interaction caused by a virtual meson cloud. Breit and Hull[2] indicated the equivalence of a boundary condition on the logarithmic derivative at a fixed distance to a deep, short-ranged, potential outside a repulsive core. Feshbach and Loman[3] have attempted to fit the nucleon-nucleon data over the range 0 to 300 Mev using the boundary condition approach. It is shown that their qualitative fit, even with small phase shifts added in the states unused by them, cannot fit the *p-p* small angle cross section and polarization angular distribution. Their $^3P_0$ phase shift is too large; reducing it by 10° still does not produce a fit.

* This research was supported by the Office of Ordnance Research, U. S. Army.
[1] G. Breit and W. G. Bouricius, Phys. Rev. **75**, 1029 (1949).
[2] G. Breit and M. H. Hull, Am. J. Phys. **21**, 184 (1953).
[3] Feshbach and Loman, to be published in Phys. Rev.

X9. Calculation of Neutron Scattering from the Complex Potential Model.* J. SOKOLOFF, *Argonne National Laboratory and Northwestern University,* AND M. HAMERMESH, *Argonne National Laboratory.*— The survey of angular distributions of scattered neutrons in the range 50 to 1500 kev by Langsdorf and Lane[1] has provided an opportunity for a critical evaluation of the validity of the Feshbach, Porter, and Weisskopf[2] model of nuclear reactions. We have compared the neutron angular distributions provided by Langsdorf and Lane with calculated cross sections using the complex square-well of FPW and a cut-off complex harmonic oscillator potential. The latter potential has the same number of parameters as the square-well and is about as suitable for machine computation. Comparison will also be made of the Legendre polynomial expansion coefficients of angular distributions obtained from the experimental data with the same coefficients obtained from theory, using both the square-well and harmonic oscillator potentials.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] A. J. Langsdorf, Jr., Bull. Am. Phys. Soc. Ser. II, **1**, 220 (1956).
[2] Feshbach, Porter, and Weisskopf, Phys. Rev. **96**, 448 (1954).

X10. Calculations Relating to the Asymmetric Fission of Pu^{239}.* PETER FONG, *Utica College of Syracuse University.*—According to a statistical theory[1] the relative probability of a mode of fission depends essentially on the total excitation energy of the two fission fragments. The excitation energies may be calculated with the aid of an empirically corrected atomic mass formula.[1] A difficulty of this theory arises in the fission of Pu^{239} that the excitation energy *versus* mass ratio curve calculated according to the theory has two peaks.[2,3] New calculations are made employing more recent mass formulas. Using a mass formula proposed by Green *et al.*[4] the excitation energy curve obtained has one single peak in the asymmetric region. Using another mass formula proposed by Levy,[5] the excitation energy curve also has one single peak in the asymmetric region and the two curves are similar. Thus, the previous difficulty seems to be due to the inaccuracy of the previous mass formula and the new mass formulas seem to support the view that excitation energy plays an important role in the determination of the relative probability of a fission mode.

* Supported by the National Science Foundation.
[1] P. Fong, Phys. Rev. **102**, 434 (1956); **89**, 332 (1953).
[2] P. Fong, Report appearing in Annual U. S. Atomic Energy Commission Progress Report by the University of Chicago nuclear chemistry group, March, 1955 (unpublished).
[3] J. K. Perring and J. S. Story, Phys. Rev. **98**, 1525 (1955).
[4] A. E. S. Green, *Nuclear Physics* (McGraw-Hill Book Company, Inc., New York, 1955).
[5] H. B. Levy, U. S. Atomic Energy Commission Document UCRL-4588 (November 30, 1955).

X11. On the Level Density of a System of Fermi Particles.* NORBERT ROSENZWEIG, *Argonne National Laboratory.*—We have attempted to analyze the assumptions underlying the derivation of the familiar formula,[1]

$$R(N,Q)=\frac{\exp\{\pi[\frac{2}{3}Q\rho(\epsilon_0)]^{\frac{1}{2}}\}}{(48)^{\frac{1}{4}}Q}, \qquad (1)$$

for the level density of a highly degenerate system of N identical noninteracting Fermi particles at an excitation energy Q. If the individual particle density ρ follows a power law, then for high degeneracies, $R(N,Q)$ is a power series in $1/\alpha^2$ (α is the degeneration parameter) of which Eq. (1) is the constant term. This provides a degeneracy criterion for the validity of Eq. (1). Thereby it is also proved that two terms of the Sommerfeld series will generally give only the constant term correctly. However, the cases of constant or linearly rising densities ρ form notable exceptions. The conditions for the validity of the saddle-point method at high degeneracy have also been derived.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] C. Van Lier and G. E. Uhlenbeck, Physica **4**, 531 (1937).

X12. On Isotropic Spin of Antiparticles. M. SUGAWARA,* *Purdue University*† (introduced by D. C. Peaslee).—Lepore[1] has argued that protons and antiprotons (or neutrons and antineutrons) should be assigned the same eigenvalues of τ_3, isotopic spin operator describing nucleons, by requiring that a theory involving nucleons, mesons, and electromagnetic field should be invariant under charge conjugation. The present note is to remark that, although his approach is quite correct, his interpretation is not entirely satisfactory, since it rests on one-particle Dirac theory. We should correctly base ourselves on field theory and calculate the eigenvalue of the total isotopic spin operator $\int\psi^*\tau_3\psi dv$ of the nucleon field in a one-antinucleon state. Such considerations have already been given[2]; they showed that protons and antineutrons have the same eigenvalue, which is opposite to that of neutrons and antiprotons, without arbitrariness in these assignments.

* On leave of absence from Hokkaido University, Sapporo, Japan.
† Assisted by the Office of Scientific Research, Air Research and Development Command.
[1] J. V. Lepore, Phys. Rev. **101**, 1206 (1956).
[2] T. Hamada and M. Sugawara, Progr. Theoret. Phys. (Japan) **8**, 256 (1952).

X13. Electrodynamics of Antiparticles. JOSEPH G. BARREDO,* *Rocasolano Institute C.S.I.C.*—Relativity deals with electrodynamics of moving but not reacting particles, yet a particle is apparent only when reacting with another particle. To deal with annihilation of particles the equation $M=(4qd^2/m)^{-\frac{1}{2}}M^{\frac{1}{2}}t^{-}$ was deduced, using the trion concept that predicted the chrono-superconductivity effect.[1] This equation gives the annihilation rate of antiparticles, e.g., negatrons and positrons forming positronium, as a function of the number of metons, M, i.e., metastable antiparticle pairs belonging to trions, the mass (isotopic effect), m, the charge, q, the length of the dipole, d, and the time, t. The value 0.5 of the exponent was found to be experimentally 0.5 ± 0.001 which emphasizes Fermi's desire for a new effect to improve field theory and Pauli's for a mathematico-epistemological revision of quantum electrodynamics. It is de Broglie's and Pauli's idea that a mathematical revision alone is not enough to solve the metaphysical difficulty that matter cannot be represented as energy tensors and electrically charged particles simultaneously.[2] Meton electrodynamics avoids this difficulty by considering systems of particles as systems of transient states.

* Now at the University of Chicago.
[1] J. G. Barredo, Phys. Rev. **98**, 1542 (1955); Naturwissenschaften **43**, 51 (1956).
[2] E. Fermi, *Elementary Particles* (Yale University Press, New Haven, 1950), p. 3; W. Pauli, *Niels Bohr and the Development of Physics* (McGraw-Hill Book Company, Inc., New York, 1955), p. 30; Albert Einstein, *The Meaning of Relativity* (Princeton University Press, Princeton, 1956), p. 81.

SATURDAY MORNING AT 10:00

Sage Hall

(W. W. WATSON presiding)

Invited Papers

Y1. Research at the Radiation Laboratory, McGill University. J. S. FOSTER, *McGill University.* (30 min.)

Y2. Willard Gibbs and Experimental Science. L. P. WHEELER, *Yale University (retired).* (30 min.)

Y3. Highlights of the History of Microwave Propagation Well beyond the Horizon. T. J. CARROLL, *Lincoln Laboratory.* (30 min.)

SUPPLEMENTARY PROGRAMME

SP1. Method of Demonstrating Kinks in Liquids.* GEORGE ANTONOFF, *33 Tier Street, New York 64, New York.*—The curves of densities of liquids d_L and those of vapors d_v are (1) $d_L=A_1+B_1t-Ct^2$ and (2) $d_v=A_2-B_2t+Ct^2$. Both are complementary: d_1-d_v is a straight line; $d_1-d_v=d$ has an enhanced curvature, because Ct^2 is doubled. Thus in d curves kinks become visible to the eye. Drawing shows it clearly if a flexible steel ruler is used. A straight line between two kinks is given by d^1. Total curve shows kinks as an intersection of the above straight lines. The kinks occur at t^0 when the value of association factor $X=d_L/d_v=4$, 8, 16, 32, 64, etc. This is a general law of nature, whose importance cannot be minimized. Choosing 3 equidistant points on the D_L and d_v curves, one calculates the constants for (1) and (11). These equations give a perfect agreement with experimental data between two kinks and diverge immediately outside. Thus kinks can be accurately located.

* To be given at the end of Session L if the chairman rules that time permits.

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Ehrlich, Gert—L1
Elwyn, A. J. and F. B. Shull—B7
Evans, A. E., Jr., D. V. Breitenbecher, D. W. Cady, and L. L. Antes—A3
Fischer, P. G. and A. V. Bushkovitch—X4
Flynn, John M. and Selby M. Skinner—L3
Foner, S. and H. H. Kolm—U6
Fong, Peter—X10
Foster, J. S.—Y1
Frederikse, H. P. R. and W. R. Hosler—U2
Frost, L. S.—H8
Fuls, E. N., P. R. Jones, and E. Everhart—L7
Garrett, C. G. B. and W. H. Brattain—N2
Gatchell, E. K.—R8
Gaynor, Joseph and Selby M. Skinner—L4
Geballe, R. and D. S. Burch—H2
Geiger, J. S., H. E. Radford, and V. W. Hughes—C12
Genser, M. and W. P. Allred—F3
Gibbons, M. D., V. L. Stout, and P. D. Zemany—A6
Gonser, U. and B. Okkerse—U10
Gourary, B. S. and F. J. Adrian—F9
Graetzer, H. G. and A. B. Robbins—B2
Hassler, F. L., F. E. Steigert, and G. F. Pieper—B4
Hein, R. A., W. E. Henry, and N. M. Wolcott—I3
Hickmott, T. W. and G. Ehrlich—L2
Hough, P. V. C. and R. O. Winder—K3
Houston, J. M.—W3
Hrostowski, H. J. and R. H. Kaiser—N12
Hughes, Vernon—S2
Hutchison, Dwight A.—H9
Innes, F. R. and C. W. Ufford—X2
Johnson, F. M. and A. H. Nethercot, Jr.—C11
Kane, Evan O.—F4
Keyes, R. J. and S. Zwerdling—U8
Knight, W. D. and R. R. Hewitt—C6
Kraybill, H. L.—R1
Landwehr, George—D5
Laponsky, A. B. and N. Rey Whetten—A4
Lax, Benjamin and K. J. Button—U7
Lee, L. L., Jr., and F. P. Mooring—B8
Leiss, J. E., J. M. Wyckoff, and H. W. Koch—D1
Lewis, H. W. and W. T. Joyner—B3
Linden, Bernard R. and Philip A. Snell—W1
Low, W.—C7
Mandel, M. and A. H. Barrett—D4
Margenau, Henry—D6
Markham, Jordan J.—F8
Marton, L., D. C. Schubert, and S. R. Mielczarek—W4
McKay, K. G.—S4
Mills, C. B.—A7
Morse, R. W.—V2
Mrozowski, S.—V4
Mueller, E. W.—P1
Munick, R. J.—W8
Murray, R. B. and J. Schenck—R5
Norton, F. J.—P2
Novick, R. and E. Commins—H10
Nowick, A. S.—V1
O'Brien, Mary C. M.—U5
Overseth, O. E., Jr.—B6
Passerini, H. J. and W. S. Ament—C8
Paulissen, G. T. and B. G. Goldring—B12
Pearse, C. A.—X7
Pearson, G. L., W. T. Read, Jr., and W. L. Feldmann—N9
Pentz, N. and J. Aron—N1
Preiss, John W.—W2
Ramsey, N. F.—G3
Reiling, G. H. and E. B. Hensley—F10
Reiss, Howard—F1
Rice, Stuart A. and William Klemperer—D2
Roberts, T. R. and S. G. Sydoriak—I6
Robertson, Harry S.—H7
Robl, H. R.—X3
Rosenzweig, Norbert—X11
Sampson, Douglas and H. Margenau—N11
Saperstein, Alvin M.—X8
Sarles, L. R. and R. M. Cotts—C2
Schultz, H. L.—G2
Schulz-DuBois, Erich—H4
Schulz, G. J. and R. E. Fox—H11
Segall, B.—X1
Segel, S. L. and R. G. Barnes—C4
Setlow, F. B.—P4
Shepherd, W. G.—A8
Singer, J.—U4
Singh, R. P.—H6
Skinner, Selby M. and Brice Carnahan—L5
Sladek, R. J.—F5
Smith, A. B., P. R. Fields, and A. M. Friedman—B10
Smith, Stephen, J. and Lewis M. Branscomb—H1
Sokoloff, J. and M. Hamermesh—X9
Speck, D. R.—C3
Spicer, W. E.—F6
Sternglass, E. J.—W6
Stirling, W. L. and N. Goldberg—K6
Sugawara, M.—X12
Sydoriak, S. G. and T. R. Roberts—I5
Taylor, J. C. and B. R. Coles—V7
Thornton, W. A.—W7
Tomasch, W. and N. Pentz—V3

Tomlinson, E. P.—R6
Torrey, H. C. —C1
Trivisonno, N. M., Selby M. Skinner, and Lieng-Huang Lee —L6
von Herrmann, P. and G. F. Pieper—B5
Wagener, S.—L10
Walsh, P. J.—H5
Walters, A. E., C. A. Fenstermacher, L. Rosler, R. G. Bennett, C. K. Bockelman, H. L. Schultz, and W. G. Wadey—R4
Weiser, Kurt—N4
Wertheim, G. K.—N10
Wheeler, L. P.—Y2
Whetten, N. Rey and A. B. Laponsky—A5
Willis, William—K1
Wolcott, Norman M.—I2
Wolsky, S. P. and A. B. Fowler—N3
Yagoda, Herman—R10
Yarnell, J. L., W. E. Stein, and H. L. Smith—B11
Young, J. R.—W5
Zwerdling, S., R. J. Keyes, S. Foner, H. H. Kolm, H. Lipson, D. Warschauer, B. Lax, and W. Paul—U9

Proceedings of the American Physical Society

Minutes of the Meetings of January through April, 1956

IN the "old days," which ended with 1955, we used to republish the abstracts of the papers contributed to our meetings in *The Physical Review* and introduce them with a little preamble comprising information about the attendance at the meeting, the banquet, and a few other remarks about the meeting itself (and also the lists of candidates elected by the Council to Fellowship and to Membership in the Society, which lists appear elsewhere in this *Bulletin*). Now that the abstracts appear in advance of the meetings once and for all, these little so-called "Minutes" are orphaned, and perhaps should be discontinued; but we will continue them for 1956 at least.

The **1956 Annual Meeting,** held in New York from January 30 to February 3, had the enormous registration figure of 3206; but we cannot take credit for this to ourselves, for ours was a part—though much the most voluminous part—of the twenty-fifth anniversary meeting of the American Institute of Physics, whose powers as a magnet evidently outdo ours by quite a lot. The banquet similarly achieved a record attendance of 546, but it was the banquet of the Institute, and all of the Founder Societies thereof, and is not to be taken as a precedent. The after-dinner speakers were Frederick Seitz, Chairman of the Governing Board of the Institute; I. I. Rabi, whose topic was "International Cooperation in Science"; and Dr. Jerome Schweitzer of the dental profession, who diverted us from the concentration of a long day devoted to physics by a fascinating illustrated discourse on his scientific explorations of the Great Barrier Reef of Australia. The Retiring Presidential Address of R. T. Birge, "Physics and Physicists of the Last Fifty Years," will have appeared in *Physics Today* before this Bulletin reaches its readers. Of the trio of speeches arranged by the Institute, those of H. G. B. Casimir and J. A. Stratton have already come out in that journal and that of J. R. Oppenheimer will follow. Our sessions were distributed over four-and-a-half days instead of the heretofore customary three: this change mitigated the problem of simultaneous sessions so much, and also made it so much easier to get meeting places close together, that we shall probably stage four-day meetings in New York hereafter. The number of contributed papers was 366. The arrangements were handled by S. A. Korff, as Chairman of the Local Committee, and by the Institute; the ladies' programme by Mrs. J. B. H. Kuper.

The **1956 Southwestern meeting** was held on February 24 and 25 in Houston at the Rice Institute. This made the greatest imaginable contrast with the Annual Meeting and was particularly delectable to those of us (apparently a considerable number) who like small meetings: the registration was 313, the attendance at the banquet 146, the number of contributed papers 84. The location of the meeting in the state of Texas made it possible to stress geophysics, and the presence of a number of neutron physicists convoked for another meeting made it possible to have two half-day sessions of invited papers in neutron physics. At the banquet we were again diverted from our labors by a quite extra-physical topic, travels and archaeological explorations in South America. The admirable speaker was Dr. Carey Croneis of the Rice Institute. We always feel abashed at asking for such services from people who are not physicists, and therefore have no reason to favor our Society, but we have always been remarkably fortunate in finding such people. The Chairman of the Local Committee was C. W. Heaps, who has now served us three times in this capacity at Houston.

The **1956 March meeting,** held in Pittsburgh, was again a great contrast to the two preceding. The March meeting is the one which several years ago our Divisions of High-Polymer Physics and Solid-State Physics agreed to accept as their prime meeting of the year. Knowledge of this fact has become so widespread, and the tradition so firmly set, that the contributed papers outside of these two fields made up only one session! The registration figure was 914, a massive figure and yet to our surprise inferior to the registration (an even thousand) in Baltimore the year before; the banquet was attended by only 158, a deplorably low number. Contributed papers numbered 224. The after-dinner speakers were P. D. Foote and Hermann Mark, the former of whom commented on the changes in physics during his career, while the latter unexpectedly and pleasantly diverted us from physics to skiing. The institutions which housed our sessions were the Carnegie Institute of Technology, the Mellon Institute, and the University of Pittsburgh. The Chairman of the Local Committee was David Halliday. It should be mentioned that Pittsburgh became suddenly and amazingly beautiful during the meeting because of a deep dense snowfall.

The **1956 Spring meeting** was held, as usual, at Washington and was, as usual, a very large meeting in which nuclear physics predominated though not by very much. The registration was 1744; the number of contributed papers 393; the attendance

at the banquet in the Shoreham Hotel was 304. Both for the Annual Meeting and for the Washington meeting, the number of contributed papers appears to be leveling off; it is hoped that this is not a transient plateau in a continuing rise. The John Scott Award of the City of Philadelphia was presented to Jesse W. Beams at the banquet. The after-dinner speakers were Arthur Roberts and H. S. W. Massey, the latter of whom became the first President of the Physical Society of London ever to address a gathering of ours. The sessions were housed in the National Bureau of Standards, the Sheraton Park Hotel, and the Shoreham Hotel.

The Chairman of the Local Committee was R. D. Huntoon of the National Bureau of Standards, who for the second time carried through with conspicuous and laudable success the enormous task of housing and managing our meeting. His Committee comprised W. R. Tilley and R. A. Elmendorf of the National Bureau of Standards, F. N. Frenkiel of the Applied Physics Laboratory, W. C. Hall of the Naval Research Laboratory, J. H. McMillen of the National Science Foundation, H. Tatel of the Department of Terrestrial Magnetism, D. F. Bleil of the Naval Ordnance Laboratory, S. F. Singer of the University of Maryland, and L. Slack of George Washington University. The ladies' programme was arranged and managed by Mrs. F. M. Defandorf, and it is gratifying to record that ninety-one of the visiting ladies took advantage of it. Mrs. Defandorf was assisted by over thirty of the Washington ladies, and we cannot even guess at the number who assisted the Local Committee. Our thanks are due all of them.

Dr. Huntoon instructed the lantern operators to estimate the attendance not only at each session, but at each paper of every session. The data show that, of the thirty-three sessions of contributed papers, only one had an attendance reaching 200, only three others surpassed 100, and only six others attained 100: many of the invited papers achieved 400 listeners. This is mentioned because it may provide a justification for accepting smaller halls for contributed papers at future meetings, should some of the larger ones become difficult or impossible to obtain.

K. K. D.

Elected to Fellowship on January 30, 1956: D. E. Alburger, Rudolf Bechmann, R. H. Bube, W. K. Ergen, Ugo Fano, B. R. Gossick, S. N. Gupta, Frank Herman, P. H. Keesom, E. F. Lowry, A. R. Moore, L. S. Nergaard, D. C. Peaslee, P. L. Smith, and F. A. Valente.

Elected to Membership on January 30, 1956: [a]Ibrahim Hasan Adawi, [a]Peter Glover Aline, [a]Carl Howard Albright, [a]Halsey Leonard Allen, III, [a]Harry Alter, [a]Robert Clyde Amme, Harvey Jerome Amster, Donald Gene Anderson, George Wesley Anthony, Tsunesaburo Asada, Harold N. Ballard, Manoj Kanti Banerjee, [a]Stephen Joseph Barone, Augusto Battig, [a]J. Lambert Bear, Charles LeRoy Beckel, [a]Robert Ernest Behringer, Emil Benko, [a]Selwyn Solomon Berg, [a]David Abraham Berkowitz, [a]Richard Thomas Bettinger, [a]Philip Raymond Bevington, [a]Vidya Bhushan Bhanot, [a]Arthur Gilbert Blachman, Joseph Blanc, [a]Richard Blankenbecler, [a]Robert Blau, John Lee Bogdanoff, Charles Brecher, Paul Erskine Brown, Michael Edwin Browne, [a]Morton Kremen Brussel, Edward Walter Burke, Jr., John Werner Cahn, Bernard Caras, [a]Russell Carl Casella, [a]Thomas Noel Casselman, [a]John Joseph Connelly, Jr., [a]John Charles Corelli, [a]Langdon Teachout Crane, Jr., Justin Calhoun Crawford, [a]Lawrence Frederick Dahl, Charlotte Anne Dames, [a]Dwight Hills Damon, Horace Redington Danner, William Chester Davis, [a]Robert Francis Deery, John Scott Desjardins, Georges Destriau, Thomas Ward DeWitt, Franklin Dunbar Dexter, [a]Robert Lee deZafra, Luigi A. Radicati di Brozolo, [a]Wesley Osborne Doggett, Robert Edwin Douty, Robert Edward Doyle, Bobby Johnson Duncan, [a]Leo Benedict Dungan, Murray Eden, Christie Jayaratnam Eliezer, [a]MacLellan Emshwiller, Albert Edwin Evans, James Evans, Joseph Farber, Frederick Edward Fay, [a]Alfred Stuart Fischler, [a]James Herbert Foote, Robert Carl Frank, [a]Sandor Jan Freedman, Marion M. Fulk, George Tadaharu Furukawa, [a]Gary Shelton Gayron, Alexander Jacob Glass, George J. Goldsmith, Albert Goodman, Paul Ernest Grant, Michael Louis Gross, [a]Joseph Gruenebaum, James A. Grundl, [a]James Louis Gumnick, [a]Gerhard Ernest Hahne, Francis R. Halpern, [a]William Oliver Hamilton, John Vincent Harrington, William James Hartin, David Kast Hartman, Francis Xavier Hassion, Takeo Hayashi, Karl Theodor Hecht, Donald Walter Hendricks, Burton Lehman Henke, Leon Joseph Heroux, John Chardon Herrera, Seymour Hilsenrath, Jerome Edgar Holliday, [a]John Joseph Hopfield, William John Houghton, Bland Bryan Houston, Jr., Franklin Charles Hurlbut, Kuninosuke Imaeda, [a]Donald Herbert Jinney, Paul Edward Tyson Jensen, Ralph E. Johnson, William Gaston Johnson, Eizo Kanda, [a]Richard Andrew Kane, Martti Heikki Kantola, Suekichi Kawata, [a]Donald Verne Keller, [a]Warren Leslie Kennedy, [a]Shoon Kyung Kim, [a]Young-Nok Kim, Jack B. Kinsinger, [a]Daniel J. Kleitman, Herbert Twombly Knight, John Peter Knudsen, [a]David Kotelchuck, Olen Kraus, Esther Krikorian, Richard Henry Kropschot, [a]Nowhan Kwak, [a]Richard Conley LaForce, William Dale Lanning, [a]Howard Joseph Laster, James Raymond Lawson, Herman R. Leider, [a]Harold Ralph Lewis, [a]Clyde Nimmer Lindner, Samuel Loshaek, Winston Allen Love, Ralph Dupps Lynn, Leslie MacGregor Mack, [a]William Cannon Mallard, Philip L. Marsden, Edward Ambrose Martell, Philip Warren Martin, [a]Jon Mathews, Jackson David Maxey, Harold A. May, [a]Sylvester Warren Mead, III, Ulrich Meyer-Berkhout, [a]Michael Francis Millea, [a]Marvin Miller, Robert Carmi Miller, [a]Roger Conant Millikan, Arthur J. Mills, Walter Grahn Nilsen, Richard Arthur Moore, Leon Owen Morgan, John Ross Mosley, †Jotindra Bhushan Mukerji, Wilbur Charles Myers, Toshimitu Nagakura, [a]Neal Dow Newby, Jr., [a]Harry Herman Nickle, [a]Philippe Pierre Nozieres, Joseph Robert O'Connor, [a]John Edward Osher, [a]Joseph Nicholas Palmieri, [a]Joseph J. Partyka, Marcel Patry, [a]Samuel Penner, Alvin Victor Pershing, Richard Pertel, Stefano Petralia, [a]Michael Dimitri Petroff, John Charlton Polkinghorne, [a]Richard Edwin Prange, [a]Richard Houghton Pratt, [a]Joseph Earl Price, [a]James Hughes Racette, Donald Stephen Rampolla, [a]Charles William Reich, Stuart Alan Rice, [a]James Dana Richards, [a]James Wyman Richardson, James Walter Ring, [a]Sergio Rodriguez, Jean Roig, William Burford Rose, [a]Bernard Rosen, [a]Jerome Leonard Rosen, [a]Myron Martin Rosenthal, [a]Harold Roth, Prince Earl Rouse, Jr., [a]Jun John Sakurai, Arthur Salop, Takao Sato, Johannes Samuel Schaffner, [a]Robert Fournier Schneider, Edward Robert Schrader, [a]Jack Schwartz, Robert S. Schwartz, Georgiana Winthrop Scovil, Hisao Sekiyama, [a]Carl Shakin, Edward Shapiro, Robert Howard

† One sponsor. Approved by K.K.D.

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Elected to Membership on March 15, 1956: J. George Adashko; Ferris E. Alger, John J. Allport, *Leonard Erwin Alsop, Avraham Amith, *John D. Anderson, Tadashi Arai, Emil Arnold, *Marshall Baker, Peter Anthony Barakos, David Barfield, Charles Adolph Barth, Clayton Wilson Bates, Jr., John C. Beckerle, Robson H. Black, *Benjamin Jacob Bloch, Edward C. Booth, *Ted Clay Bradbury, Arthur Albert Brant, Fred R. Buskirk, Crispin Calvo, Allan E. Carlson, Edgar Bishop Charles, *Chellis Chasman, Arthur B. Clegg, *Leonard Cohen, Theodore J. Coletta, John L. Dalke, Halyor T. Darracott, *Charles Otto Dechand, Gerard de Saussure, Warren DeSorbo, Bernard H. Duane, Herbert Spencer Dunkerley, *Leonard J. Eisenberg, *Shelden Douglass Elliott, Jr., R. Hobart Ellis, Jr., Warren T. Eriksen, *Frederick J. Ernst, Robert Charles Erwood, Erwin P. Fischer-Colbrie, Jack J. Forney, *John D. French, *S. Terry Friedman, Calvin Weston Gillard, *Joseph A. Giordmaine, Lawrence M. Grossman, Chester P. Guild, *Zaven Geo. Guiragossian, *Ishwar C. Gupta, *Ernst W. Hamburger, *Eastman Nibley Hatch, *Joseph R. Hearst, Lewis A. Hofstatter, Dan H. Holland, Amos G. Horney, Henry James Hroch von Dalebor, *Albin I. Johnson, *Frank Culver Jones, Walter M. Kane, *Paul S. Kelly, *Lee Joseph Kieffer, Young B. Kim, N. M. Kindell, Francois F. Kirchner, Carl L. Kober, Bela G. Kolossvary, *Arthur F. Kuckes, Walter R. Lamb, Mike Lauriente, Harold Vincent Larson, Gerard LePoutre, Roland Lindner, *Carl Arnold Ludemann, Walter W. Malinofsky, *Visvaldis Mangulis, *Stewart M. Marcowitz, James M. McCampbell, Robert E. McCoskey, Sakae Minami, *Thomas Irving Moran, Thomas Nolen Morgan, John B. Morrice, Hiroyuki Nagai, *Michael Navenberg, *Edward Alfred Nelson, *Oliver Enoch Overseth, Jr., *John Lee Pack, Ashton M. Patterson, *L. Donald Pearlstein, Elbert Andrew Pence, Jr., J. Fred Peoples, Armin R. Perry, Jr., Richard Albert Porter, Robert William Powers, *Matthew Prastein, Albert William Saenz, *Guy Schupp, Erich G. K. Schwarz, Donna Jean Seaman, Glenn E. Seay, Leslie B. Seely, Jr., *Philip E. Seiden, James M. Sharp, *Vincent Wymore Shiel, Ross E. Shrader, *Ralph Oliver Simmons, *George Elwood Smith, Robert T. Smith, Jr., Thor L. Smith, *Joseph T. Sparks, *David Ralph Speck, Otmar M. Stuetzer, Paul R. Swan, *James David Talman, *Robert T. Teragawa, *Rudolph Charles Thom, *Jan Peter Toennies, *Johannes Tuul, Michiyuki Uenohara, Paul David Vachon, *John C. Vander Velde, Richard van der Walt, *Peter Oliver Vandervoort, Harold Blackman Vernon, Richard Herman Vogt, *Ronald G. Weirick, Leonard R. Weisberg, Morton S. Weiss, *Donald Otis Wells, *Frederick Gustav Werner, J. M. Whelan, Arthur Frank Wickersham, Jr., *Wentworth Williams, Jr., *Perry Baker Wilson, Arthur Edson Woodruff, *Hajime Yoshiki, *Leon N. Zadoff, Lloyd Robert Zumwalt, Earl Frederick Zwicker.

Elected to Membership on April 25, 1956: *Harold E. Adelson, Edward F. Allen, *Matthew A. Allen, John H. Anderson, *Robert G. Arns, Andre Joseph-Balnc-Lapierre, *Richard G. Bardes, *William A. Barrett, Jr., Lawrence Sims Bartell, Johannes G. Bellak, *Robert B. Bennett, Jeremy Bernstein, Dwight Winton Berreman, Arthur Irwin Bienenstock, Albert Burger, *David L. Burk, Claude S. Burtnette, Jr., Faye R. Chabrow, Harry Ray Child, Jack Chin, Homer Eugene Conzett, *John Edwin Crew, *Charles Mitchell Davis, Jr., *Edward Alex Davis, *David Holmes Douglas, Jr., Hans Ulrich Eckert, *Palmer L. Edwards, *Theodore Harry Einwohner, David Fisher, *James Ambrose Ford, Jr., *Jesse W. Foreman, *Zeev Fraenkel, W. J. Fredericks, *Ronald Fuchs, *Marvin Garfinkel, *William I. Ginsberg, Littie Ann Glover, *Aurel Goodwin, Jr., Clifford M. Gordon, *Michael Grasso, William B. Green, Donald William Griesinger, Claus H. Haake, Nathan Isaac Hall, Tatsuji Hamada, *Robert Hugh Hammond, Akira Hashizume, Norval J. Hawkins, Walter H. Heintz, *William M. Henebry, Erich B. Henschke, Charles Maria Herzfeld, Jean-B. F. Hocepied, Richard W. Hoff, Arthur W. Hornig, *Takeo Izuyama, *Oleg Jefimenko, *Jose O. Juliano, *Theodore E. Kalogeropoulos, *Hiroshi Kamimura, *Ronald Eugene Kettler, Takeshi Kojima, *Nicholas A. Krall, *I. Richard Lapidus, *Serge Michel Lapointe, Willi Lehmann, *Gerald Stanley Levy, Ellis Redgway Lippincott, Marjorie J. Littleton, Thomas R. Long, *Bogdan C. Maglich, *Glen A. Mann, John James McArtney, William E. Meyer, *Dietrich Meyerhofer, *Gary Earl Mitchell, *Parker E. Moreland, Jr., *Glen J. Morris, Ove Nathan, *Wesley A. Nelson, Robert Jack Neuhold, Roy H. Neynaber, *Knute J. Nomland, Masaharu Okano, Everette C. Olson, *Raymond Lee Orbach, John Overend, Robert P. Pagliarulo, *Victor Kenneth Pare', Arthur S. Pavlovic, *James C. Phillips, Paul C. Phillips, Heinz Pick, Charles Lane Poor, Kevin H. Prendergast, Valdemars Punga, Jarus William Quinn, Conrad T. Rauch, Clifton W. Reed, William W. Robertson, *Robert J. Robinson, *Robert Nicholas Rogers, *Moti L. Rustgi, *Fritz Duane Schupp, *Frederick Downing Seward, *John George Siambis, *Kwang Yun Shen, *Meyer Sirotkin, Friedolf M. Smits, *Park Tong Soo, Henn H. Soonpaa, *Robert Ryder Spencer, David Spielberg, Michael M. Szwarc, Lawrence Talbot, Ellison H. Taylor, *Herbert George Trostle, *Harvey L. Vredeveld, *Peter J. Warter, Jr., *George Michael Weyler, Jr., *Carlos V. Wheeler, Milo M. Wolff, *John Lang Worcester, *Stanley T. Wray, Jr., *Thomas Edward Young, Lowell Zeid, Jerry H. Zenger, *Melvin Joseph Zucker.

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* Student.

Errata Pertaining to Abstracts B3, H5, JA3, JA7, L3, MA5, NA2, and SP1 of the 1956 New York Bulletin (Series II, Volume 1, No. 1)

B3, by J. H. Van Vleck. The formula for Δ given in this abstract is valid when there are crystalline fields but not when there is interatomic coupling. The second term should contain a factor B^2.

H5, by L. T. Aldrich, G. W. Wetherill, G. L. Davis, and G. R. Tilton. In line 17, instead of "$a\lambda_\epsilon = 3.2$ dpm/gram K," read "$a\lambda_\epsilon = 3.2$ dps/gram K."

JA3, by W. W. Buechner and A. Sperduto. In line 11, instead of "and in Fe^{56} at 0.36, 0.85, 2.08," read "and in Fe^{56} at 0.85, 2.08."

JA7, by Berol L. Robinson and Richard W. Fink. For the Q-values in the table, instead of "-0.3 ± 0.4, -1.53, ~0, -0.92," read "$+0.6\pm0.2$, -2.04, ~0, -2.05."

L3, by P. K. Kabir and E. E. Salpeter. The following footnote should be added: "Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission."

MA5, by N. Sclar. In line 5, instead of "approximations that require $ka \ll 1$," read "approximations that require $ka \gg 1$." In line 16, instead of "$(\pm q^2aD-1)^{\frac{1}{2}}$," read "$(\pm 2mq^2a/\hbar^2D)^{\frac{1}{2}}$."

NA2, by C. L. Oxley. In the title instead of "Compton Effect in Scattering of 100-Mev Gamma Rays by Protons," read "Compton Scattering by Protons in the 30–100 Mev Region."

SP1, by Stanley Winkler. In the second equation, instead of "t^2," read "t^{-2}."

Errata Pertaining to Abstracts C5 and R5 of the 1956 Houston Bulletin (Series II, Volume 1, No. 2)

C5, by Joseph G. Barredo. In line 7, instead of "$dN/dt = (4qzd/m)^{-\frac{1}{2}} - N^2t^{-\frac{1}{2}}$" read "$dN/dt = (4qzd/m)^{-\frac{1}{2}}N^2t^{-\frac{1}{2}}$."

R5, by Robert L. Chuoke. In line 14, instead of "all W, W_c," read "all W greater than W_c."

Errata Pertaining to Abstracts P6 and R8 of the Pittsburgh Bulletin (Series II, Volume 1, No. 3)

P6, by V. J. Folen and G. T. Rado. In reference 2, instead of "National Research Laboratory," read "Naval Research Laboratory."

R8, by Alvin J. Cohen. In the title, instead of "Neutron Specify," read "Neutron Specificity."

Errata Pertaining to Abstracts FA4, G9, HA7, JA3, K9, KA3, R6, RA6, TA1, TA9, UA2, VA2, W4, and Y1 of the 1956 Washington Bulletin (Series II, Volume 1, No. 4)

FA4, by J. W. Davisson. In the title instead of "Determination of Crystal Structure," read "Determination of Crystal Symmetry."

G9, by Charles J. Taylor, Alexander Bratenahl, H. Paul Hernandez, Jack M. Peterson, Bob H. Smith, and Ralph H. Stahl. In the fourth sentence instead of "The magnetic gap is 12 in. at the center, increased by 60 mils at 35 in. radius," read "The magnetic gap is 12 in. at the center, increased by 120 mils at 35 in. radius."

HA7, by J. Weneser and E. L. Church. In the footnotes to the by-line instead of "†" read "‡"; instead of "‡" read "†."

JA3, by Francis C. Gilbert, Charles E. Violet, and R. Stephen White. In line 12 instead of "was found to be 2.3 ± 0.7 Mev," read "was found to be 4.4 ± 0.7 Mev." In line 14 instead of "a mass of 970.4 ± 5.0 electron masses," read "a mass of 966.2 ± 5.0 electron masses."

K9, by B. N. Brockhouse. In line 19 instead of "the rms proton position (Δr) to have the asymptotic form $(\Delta r)^2 = a^2 + b\Delta t$ where $a \simeq 6.5\times10^{-9}$ cms and $b \sim 3\times10^{-5}$ cm^2/sec," read "the rms radius of the proton self-correlation function to have the asymptotic form $(\Delta r)^2 = 6(u^2+\gamma t)$ where $u = 0.38\times10^{-8}$ cms and $\gamma \sim 1.5\times10^{-5}$ cm^2/sec."

KA3, by T. L. Gilbert. In the last sentence instead of "velocity on the reciprocal of the applied field and the nonrealizability of a steady state for long relaxation times," read "velocity on the applied field and the nonrealizability of a steady state for large applied fields."

R6, by E. der Mateosian and M. Goldhaber. In line 14 instead of "$|M|^2 \approx 1/15$," read "$|M|^2 \approx 1/1.5$."

RA6, by B. J. Malenka and E. Feenberg. In line 14 instead of "neutral pseudovector or vector π meson," read "neutral vector and pseudovector π meson."

TA1, by L. S. Singer and W. J. Spry. In line 6 instead of "670°C," read "890°C."

TA9, by H. C. Torrey. In line 4 instead of "local spin relaxation rate r_d correspondingly enhanced," read "local spin relaxation rate correspondingly enhanced." In line 7 instead of "the extra relaxation rate of the entire liquid," read "the extra relaxation rate r_d of the entire liquid." In line 10 instead of "$r_d = K(D_0r_0)^{\frac{1}{2}}b$," read "$r_d = K(D_0r_0)^{\frac{1}{2}}/b$."

UA2, by Jacques M. Blum. In the dagger reference instead of "Appointment supported by the OEEC," read "Appointment supported by an ICA program administered by the National Academy of Science, National Research Council."

VA2, by Robert J. Rubin. In line 10 instead of "$u_0(at) + (1/a)v_0(at)$," read "$u_0'(at) + (1/a)v_0(at)$." In line 11 instead of "$u_0(a)$ and $v_0(a)$," read "$u_0(x)$ and $v_0(x)$."

W4, by A. Sperduto and W. W. Buechner. In line 11 instead of "1.302," read "1.413." In line 12 instead of "1.644," read "1.664." Instead of "2.041," read "2.125."

Y1, by S. F. Singer. In line 14 instead of "$\alpha_0 < 2\frac{1}{2}°$," read "$\alpha_0 > 2\frac{1}{2}°$."

Minutes of Sectional Meetings

The Minutes of the 1956 Spring Meetings of our Southeastern Section and of our Ohio Section are being published in the Eugene *Bulletin* (issue No. 5 of this year) which should appear almost simultaneously with this one.

Proposed Amendment to the Constitution of the Society

During the coming season the following revision of Article VII, Section 1, of our Constitution will be proposed by our Council to the membership-at-large. Words to be added to the present text are italicized, and words to be deleted are enclosed in parentheses.

The *elective* officers of the Society shall be elected by mail ballot. Not more than three months after the Annual Meeting the Secretary shall send to each member of the Society a request for nominations, specifying the offices which are to be filled at the next election. The Council shall appoint a Nominating Committee composed of seven or nine Fellows, not more than three of whom may be officers of the Society. They shall be chosen from various fields of physics so as to represent the diverse interests of the Society as adequately as is feasible. The appointment shall be made at the Annual Meeting, and the Nominating Committee shall hold a scheduled meeting at a meeting of the Society occurring not more than seven months after the Annual Meeting. The election ballot form shall contain the names of one or more candidates nominated by the Nominating Committee for each office to be filled, and the name of any and each other candidate nominated for any office by members of the Society numbering at least one percent of the total number of members given in the latest printed membership list of the Society, *and blank spaces in which the voters may write other names.* The Nominating Committee may nominate the same persons as are nominated by the second procedure aforesaid. Copies of the election ballot shall be mailed to all members not less than eight weeks before the Annual Meeting; and the Secretary shall specify an address to which the ballots are to be sent and a deadline date not less than three weeks later than the date of distribution of the ballots. No ballot shall be counted unless unambiguously marked by a qualified voter to indicate his choices, sent in a sealed envelope bearing the voter's name, and received at the specified address not later than the specified deadline-date. *For the Presidency, Vice-Presidency, Secretaryship, Treasurership, and Managing Editorship,* a majority of all the ballots cast *for the corresponding office* conforming to these rules shall be necessary for election, *and if no candidate have a majority, the Council which is in office at the time of the election shall choose between the two leading candidates. If there are more than two candidates for the two posts on the Council, the two leading candidates shall be the winners. If there are more candidates for any type of post on the Board of Editors than there are posts of this type to be filled, the winners shall be the leading candidates to the appropriate number. If the application of these rules is frustrated by a tie, the Council which is in office at the time of the election shall decide between the tied candidates.* The counting of the ballots shall be entrusted to Tellers appointed by the President, and the winning candidates shall be announced at the Annual Meeting and in a publication of the Society. (In case of failure to secure a majority for any office, the members present at the Annual Meeting shall choose by ballot one of the two candidates having the highest number of votes for that office.)

Communication from the Treasurer

For the information of the members the Treasurer presents the following statements, condensed from the report for the year 1955 of Conroy, Smith & Co., auditors, as presented to the Council at Washington on April 25, 1956.

GEORGE B. PEGRAM, *Treasurer*

OPERATING INCOME AND EXPENSES ALLOCABLE TO THE YEAR ENDED DECEMBER 31, 1955

Income:				
Membership dues			$176 914.78	
Net income from "*Reviews of Modern Physics*"			504.88	
Receipts from dinners and registration fees		$ 5 554.63		
Deduct: Expense of meetings		1 261.92	4 292.71	
Buckley Physics Prize Award Trust (2 years)			500.00	
Sale of addressograph equipment			520.00	
Interest on bonds and savings accounts			2 152.60	
Income from book exhibits at meetings			907.46	
Miscellaneous			136.19	$185 928.62
Expenses:				
Office of Secretary and Treasurer:				
Salaries		$ 8 564.85		
Payroll taxes		157.71		
Travel expenses of officers of Society		2 404.66		
General office expenses		3 060.71	$ 14 187.93	
American Institute of Physics—collecting dues and subscriptions			12 098.97	
"*Bulletin*"—cost of printing and mailing:				
Regular issues	$ 15 145.97			
Special issue—membership list	14 070.47	29 216.44		
American Institute of Physics—editorial mechanics		897.75		
		30 114.19		
Deduct: Income from "*Bulletin*" subscriptions		1 122.50	28 991.69	
The Physical Review—American Institute of Physics				
Cost of production and distribution:				
7694 pages to 6597 member and 2719 nonmember subscribers:		278 484.50		
Deduct: Income—collected by American Institute of Physics				
from nonmember subscriptions	83 647.81			
from published articles	119 090.83			
from sale of back numbers	4 885.86	207 624.50		
Net expense		70 860.00		
Editorial office		29 915.99		
		100 775.99		
Deduct: Income from membership subscriptions		31 439.34	69 336.65	
Cost of membership and reduced rate subscriptions in excess of amounts collected therefor:				
The Review of Scientific Instruments		1 347.00		
The Journal of Chemical Physics		3 541.00		
Journal of Applied Physics		6 969.00	11 857.00	
Contribution to Institution of Electrical Engineers for "*Physics Abstracts*"			30 456.50	
Contribution for maintenance and support of American Institute of Physics, 10% of all dues collected			18 538.99	$185 467.73
Net income from operations of 1955				$ 460.89

BALANCE SHEET AS OF DECEMBER 31, 1955

ASSETS

Cash in banks			$196 933.89
Securities—at cost:			
$50 000 U. S. Treasury, 2¼%, due December 1959–1962		$ 50 836.37	
20 000 U. S. Treasury, Series F, due March 1956		14 800.00	
10 000 U. S. Treasury, Series F, due April 1959		7 400.00	
14 000 U. S. Treasury, Series K, due May 1967		14 000.00	
1 000 Baltimore and Ohio Railroad, 1st mortgage, Series A, 4%, due July 1, 1975		850.00	87 886.37
Deferred charges:			
"*The Physical Review*"—30-Year Cumulative Index (value of copies on hand)		8 761.14	
Cost of membership and reduced rate subscriptions to various journals for year 1956, in excess of amounts collected therefor		8 794.50	17 555.64
			$302 375.90

LIABILITIES AND SURPLUS

Accounts payable:			
American Institute of Physics, Inc.		$ 25 874.22	
Institution of Electrical Engineers		185.25	
Division of Chemical Physics		491.10	
Division of Electron Physics		2.00	
Director of Internal Revenue		564.60	
Teachers' Insurance and Annuity Association		164.16	$ 27 281.33
Balance of 1955 contribution to Institute of Electrical Engineers			5 456.50
Deferred credits:			
Membership dues: Year 1956	$126 058.65		
Year 1957	15.00	126 073.65	
Subscriptions from members to issues of journals to be published subsequent to December 31, 1955:			
"*The Physical Review*"	$ 43 013.78		
"*Physics Abstracts*" and "*Electrical Engineering Abstracts*"	5 964.65		
"*Bulletin*"	333.80	49 312.23	
Subscriptions collected by American Institute of Physics for American Physical Society for journals to be published subsequent to December 31, 1955		1 855.20	177 241.08
Surplus at January 1, 1955		$ 91 936.10	
Add: Net income, year 1955		460.89	92 396.99
			$302 375.90

The American Physical Society

OFFICERS OF THE SOCIETY FOR 1956

President	E. P. WIGNER	Princeton University
Vice-President	H. D. SMYTH	Princeton University
Secretary	K. K. DARROW	Bell Telephone Laboratories (Office at Columbia University)
Treasurer	G. B. PEGRAM	Columbia University
Managing Editor	S. A. GOUDSMIT	Brookhaven National Laboratory
Local Secretary for the Pacific Coast	W. A. NIERENBERG	University of California, Berkeley

Past Presidents now on Council: W. F. G. Swann, H. A. Bethe, and R. T. Birge.

Elected Members of the Council: L. I. Schiff, W. Shockley, John Bardeen, A. O. Nier, F. Seitz, A. M. Weinberg, S. K. Allison, and N. F. Ramsey.

Please cut along this line

(To be sent to Mrs. D. W. Gordon, Sloane Physics Laboratory, Yale University, New Haven 11, Connecticut.)

I EXPECT to attend the dinner of the American Physical Society at seven o'clock on Friday evening, June 22. My party will comprise .... persons.

(*Name*).....

(*Address*).....

(If you want your tickets held to the time of the banquet itself, send a check, made out to American Physical Society, for $3.25 per plate.)